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,, 16. Tool Steels.
,, 23. Defects in Steels.
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Negotiating with Government Departments in connection with any post, please communicate with the GENERAL SECRETARY, Association of Engineering and Shipbuilding Draughtsmen, 96, St. George's Square, London, S.W.1. G 786

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and SALES MANAGEMENT.—Write for brochure describing our special Course of Training for posts of unlimited scope in the lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 77, Milligate Building, Manchester. 2676

TENDERS.

THE DIRECTOR-GENERAL, INDIA STORE DEPARTMENT, Branch No. 16, Belvedere Road, Lambeth, S.E. 1, invites

Tenders for :—

POINT RODDING. Steam piping quality.
Tenders due on the 27th March, 1925.
Tender Forms obtainable from above. H 488

METROPOLITAN ASYLUMS BOARD.

TO LIFT ENGINEERS.

The Board invite separate

Tenders for the Installation of

THREE ELECTRIC PASSENGER LIFTS in the New Buildings at Tooting Bec Hospital, Tooting Bec, S.W.17, in accordance with the Specification and Drawing prepared by Mr. T. COOPER, M.Inst.C.E., M.I.Mech.E., Engineer-in-Chief. The Specification, Drawing, and Form of Tender may be inspected at the Office of the Board, Victoria Embankment, E.C.4, on and after Ten a.m. on Wednesday, 11th March, and can then be obtained upon payment of a deposit of £1. The amount of the deposit will be returned only after the receipt of a *bona fide* Tender sent in accordance with the instructions on the Form of Tender and after the Specification and the Drawing have been returned.
Tenders, addressed as noted on the Form, must be delivered at the Office of the Board not later than 2.30 p.m., on Wednesday, 25th March, 1925.
G. A. POWELL,
Clerk to the Board. H 452

GREAT SOUTHERN RAILWAYS.

The Directors of the Great Southern Railways, Ireland, are prepared to receive

Tenders for the Supply of the

following Material:
4,000 tons No. 90 R. BULL HEAD RAILS (British Standard Section).
90 tons FISHPLATES for ditto.
2,500 ,, CAST IRON CHAIRS.
6,500 ,, 85 lb. FLAT FOOT RAILS.
160 ,, FISHPLATES for ditto.
960 ,, CAST IRON SOLEPLATES.
Specifications, Forms of Tender (on which alone offers will be considered) and Drawings can be obtained on application to the Company's Stores Superintendent, Inchicore, Dublin.
Tenders should be forwarded so as to reach the undersigned not later than Ten a.m., on Thursday, 2nd April, 1925, in the envelope provided for the purpose.
The Directors do not bind themselves to accept the lowest or any Tender.
C. E. RILEY, Secretary.
Kingsbridge Terminus, Dublin.
March, 1925. H 479

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY COMPANY.

The Directors are prepared to receive up to Noon, on Friday, 27th March,

Tenders for the Supply of :—

STEEL SLEEPERS, DISTANCE PIECES AND KEYS.

Tenders must be made on forms, copies of which, with Specification, can be obtained at the e Offices on payment of 20/- each (which will not be returned).
The Directors do not bind themselves to accept the lowest or any Tender.
S. G. S. YOUNG,
Secretary.
Offices: 91, Petty France, Westminster, S.W.1.
9th March, 1925. H 474

THE GREAT INDIAN PENINSULA RAILWAY COMPANY, 48, Copthall Avenue, E.C.2, invite

Tenders for :—

1. Steel Rails and Fishplates.....Fee £1.
2. Pressed Steel Sleepers..... ,, £1.
3. Steel Fishbolts ..... ,, 7s. 6d.
4. Rolled Steel Check-Rail Bars and Fastenings..... ,, 5s.
5. Railway Tickets..... ,, 7s. 6d.
6. Solid Drawn Steel Boiler Tubes ..... ,, 7s. 6d.
7. Steelwork for Bridges..... ,, £1.

Tenders are due by Eleven a.m., on 24th March, 1925. Tender forms obtainable at above address. Fees not returnable. H 493

APPOINTMENTS OPEN.

Applications are Invited

for a VACANCY as JUNIOR SCIENTIFIC ASSISTANT in the Experimental Department of H.M. Signal School, Portsmouth. Candidates, who should not be over 30 years of age, should possess an Honours Degree in Physics or its equivalent. (Preference will be given to ex-Service men.)
The salary scale is £175-15-235, plus Civil Service Bonus, which at present increases £175 to £278 19s.
The successful candidate will be required to contribute 5 per cent. of the basic salary under the Federated Universities Superannuation Scheme, the remainder being contributed by the Government.
Applications, giving full particulars of qualifications, War Service, etc., and enclosing testimonials, should be forwarded to the SECRETARY OF THE ADMIRALTY (C.E.), Admiralty, S.W.1, not later than April 7th. H 457

ROMNEY MARSH LEVEL.

ASSISTANT EXPENDITOR.

Applications are Invited for

the POST of ASSISTANT EXPENDITOR.
Applicants should preferably be not under 30 or over 40 years of age and must be competent to make surveys and prepare plans, sections, specifications, etc., of land drainage and sea defence works, and have had practical experience of similar work.
The selected candidate will be appointed for a probationary period of six months and, proving satisfactory, may anticipate succeeding to the post of Expenditor when vacant.
Applications (accompanied by two recent testimonials) stating age, qualifications, experience and salary required, should be sent in to the undersigned on or before 30th March instant.
Canvassing will disqualify.
RICHARD S. JONES,
Clerk.
New Hall,
Dymchurch, Kent.
10th March, 1925. H 477

ROYAL AIR FORCE.

CIVILIAN EDUCATIONAL STAFF.

Applications are Invited

for VACANCIES in GRADE IV to be filled shortly. Applicants must have served in the War, 1914-1918, and preference will be given to candidates with engineering qualifications and experience.
Scale of Salary: £190-£12½-400, plus a fixed allowance varying from £40 to £90 per annum according to position on the Scale. The salary, but not the fixed allowance, is subject to a deduction of 5% for superannuation and to the voluntary abatement of 5%.
Allowance may be made up to 10 increments for war service and previous experience of a suitable character.
Appointments in any of the higher Grades are normally filled by selection from the Grade below.
Forms of application and full particulars may be had from the SECRETARY, AIR MINISTRY, Adastral House, Kingsway, London, W.C.2. Previous applicants who have notified in writing, their wish to have their name placed on the "waiting list" need not re-apply. H 489

Estimating.—Wanted, Young

Man for Estimating Department in electrical engineering company. Preferably with works practical experience. Able to work correctly to drawings. Progressive position.—Address, stating age, experience, and salary required, H 469, Offices of ENGINEERING.

Assistant to Works Manager

REQUIRED for Hosiery Machine Builders' Works. Good opportunity for young man conversant with modern shop practice.—Apply, by letter, stating experience, salary required, etc., to MELLOR, BROMLEY & CO., LTD., M. Dept., Minotaur Works, Leicester. H 504

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ENGINEER WANTED for Hosiery Machine Builders' Works. Must have had practical progressing experience with modern engineering firm.—Apply, by letter, stating experience, salary required, etc., to MELLOR, BROMLEY & CO., LTD., P. Dept., Minotaur Works, Leicester. H 503

Assistant Structural Engineer

REQUIRED with experience in Drawing Office, Estimating, Sales Office and connection with London Architects and Engineers.—Address, with full particulars, H 448, Offices of ENGINEERING.

Chief Engineer Salesman,

REQUIRED to take charge of Sales Department of large firm supplying CENTRIFUGAL LIQUID PURIFIERS. Unique opportunity for suitable man, who must have initiative, organising ability, extensive sales experience, and preferably some knowledge of centrifugals. State age and salary required, and give full particulars of qualifications and experience.—Address, H 445, Offices of ENGINEERING.

Capable Engineer and

DRAUGHTSMAN REQUIRED to take charge of small Engineering Drawing Office, near London, and be responsible for all design work and estimates to customers. Applicants must have had considerable Shop and D.O. experience in the manufacture of motor and other parts to fine limits. Good technical training essential.—Address, giving all information as to qualifications, experience and salary expected, H 450, Offices of ENGINEERING.

Experienced Engineer

WANTED for London Office to undertake sales for important firm Combustion Engineers. Technically equipped with wide experience as to boilers, stokers, and all power house problems. Good connection with leading consultants, chiefs, etc., essential. Must have compelling personality and capacity for getting entrée to and for dealing with Directorates and Corporations, etc. State age, Technical and Sales Experience, Salary, when free. —Address, H 472, Offices of ENGINEERING.

Required for Mid. East,

Assistant ENGINEER, about 26, unmarried, with General experience, including erection of Factories and Installing Machinery, some knowledge of Electric Generators and Motors, also Heavy Oil Internal-Combustion Engines, an advantage. Good prospects for suitable man.
Address, with copies only of testimonials, H 470, Offices of ENGINEERING.

NORTHAMPTON POLYTECHNIC INSTITUTE, CLERKENWELL, LONDON, E.C.1.
HEAD OF THE ELECTRICAL ENGINEERING DEPARTMENT.
THE GOVERNING BODY invite

Applications for the Vacant

POST of HEAD OF THE ELECTRICAL ENGINEERING DEPARTMENT.
The salary scale at present applicable to the post is £700-25-900 (less an abatement of 5 per cent.) The period during which the present scale (and abatement) is operative expires on March 31st, 1925, when some revision may take place following an award of the arbitrator appointed in connection with the joint standing committee on teachers' salaries.
The post is governed by the provisions of the Teachers (Superannuation) Acts.
Further particulars and forms of application may be had on application to the undersigned, to whom applications should be forwarded not later than April 18th.
S. C. LAWS, M.A., M.Sc.,
Principal. H 475

INDIAN SERVICE OF ENGINEERS, STATE RAILWAYS.

THE SECRETARY OF STATE FOR INDIA IN COUNCIL will, in 1925, appoint

Two Assistant Executive

ENGINEERS for this Service if so many suitable candidates present themselves.
Every candidate must be a British subject or a ruler or subject of any State in India in respect of whom the Governor-General of India in Council has made a declaration that he is to be considered eligible.
Candidates must be not less than 21 years and not more than 24 years of age on 1st August, 1925.
They must either (1) have obtained one of certain recognised University degrees or other distinctions in Engineering, or (2) have passed Sections A and B of the Associate Membership Examination of the Institution of Civil Engineers or been exempted by the Institution from such examination, or (3) produce the required evidence that they are otherwise eligible under the Regulations. They must in addition have had at least one full year's practical experience of Civil Engineering under a qualified Civil Engineer at the time when they appear before the Selection Committee.
Applications from candidates must reach the India Office not later than 1st April. Printed forms, together with information regarding the conditions of appointment, may now be obtained from the SECRETARY, PUBLIC WORKS DEPARTMENT, India Office, Whitehall, London, S.W.1. H 161

Civil Engineer Required

for the Harbour Engineer's Department, Colombo Port Commission, CEYLON, for two years' service with possible permanency. Salary £350 per annum for two years, afterwards rising, if confirmed in the appointment, by yearly increments of £40 to £1050 a year. The post is at present non-pensionable. Free passages. Quarters provided, if available, for which rent is payable at the rate of 10% of salary, otherwise an allowance for rent in accordance with the usual scale is paid. Candidates, not over 40 years of age, must be fully qualified Civil Engineers and have knowledge and experience in the general routine work of a Harbour Engineer's Office, Marine Surveying and Sounding, Design and setting out, and the construction of various harbour works, including quays, jetties, warehouses, railways, etc., and dredging and the removal of rock and laying of moorings. The person engaged is expected to acquire a knowledge of the Tamil language and pass a viva-voce examination in that language. He will not be eligible for confirmation in his appointment until he has passed this examination and is considered otherwise suitable.—Apply at once, by letter, stating age, qualifications and experience, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, Westminster, London, S.W.1, quoting M/13403. H 494

Engineer with knowledge of

Accounts REQUIRED to take charge of Cost Office in light Engineering Works. London district.—Address, giving details of experience, age, salary required, etc., H 427, Offices of ENGINEERING.

Engineer Wanted to Take

charge of mechanical, electrical, and maintenance operations at a glass bottle factory. Must be experienced in controlling men, and must have some experience of construction work.—Address, stating experience and salary required, H 502, Offices of ENGINEERING.

Assistant Engineers (3)

REQUIRED by the GOVERNMENT of NIGERIA for the PUBLIC WORKS DEPARTMENT for two tours of not less than 12 nor more than 18 months' service with possible extension. Salary £480 a year for first three years of service, then £510, rising to £720 a year by annual increments of £30, and thereafter to £820 a year by annual increments of £40. Outfit allowance of £60 on first appointment. Free quarters and passages, and liberal leave on full salary. Candidates, aged 25 to 30, preferably unmarried, must have had good general education and be (a) A.M.I.C.E., or hold equivalent qualifications, or (b) have passed the full examination of the Institution of Municipal and County Engineers. They must have had proper technical training and have had not less than two years' subsequent experience on large Engineering or Municipal Works.—Apply at once, by letter, stating age, qualifications and experience, also whether married or single, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, Westminster, S.W.1, quoting reference M/13422. H 473

Assistant Engineer Re-

QUIRED by the GOVERNMENT of HONG KONG for the PUBLIC WORKS DEPARTMENT for three years' service with possible permanency. Salary £460, rising to £500 a year by annual increments of £20, and thence (if appointment is made permanent) to £1000 a year, payable locally in dollars at the Government rate of exchange which is at present fixed at 2s. to the dollar. In addition, a strictly temporary exchange allowance of 20% of salary is at present paid, and thus at the present time the annual salary in dollars will be $5520 a year. The current rate of exchange being now about 2s. 4d. to the dollar, the sterling equivalent of $5520 is accordingly about £600. Travelling allowance at the rate of £240 a year. No Income Tax payable. Free passages. Candidates, preferably unmarried, 24-30 years of age, must be regularly trained Civil Engineers and have passed the Institution of Civil Engineers examination or have obtained exemption therefrom by an exempting degree. Must be good draughtsmen, proficient in land surveying and levelling. Should preferably have had experience in maintenance work of Waterworks of a large town and some experience in Waterworks Construction.—Apply, at once, by letter, stating age, qualifications and experience to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, S.W.1, quoting M/13411. H 454

THE CORPORATION OF TRINITY HOUSE.

APPOINTMENT OF ASSISTANT ENGINEER.

Applications are Invited for

the APPOINTMENT of an ASSISTANT ENGINEER. Age 28 to 35.
Candidates must be A.M.I.C.E. by Institution or equivalent examination. They should be quick and neat draughtsmen, proficient with theodolite and level, able to draw up complete specifications, take out quantities, and write reports. A thorough knowledge of building construction, ferro-concrete, steel structures and sea works essential. General all-round knowledge of Engineering, including electrical and wireless work, is a qualification.
Commencing salary £400 per annum, rising to £600 per annum, plus bonus.
Applications, stating age, qualifications and experience, accompanied by copies of not less than three testimonials, to be addressed to the SECRETARY, Trinity House, London, E.C. 3, not later than the 20th March, marked outside "Applications re Assistant Engineer." H 390

Assistant Engineer Re-

QUIRED for the Port Development Department of HONG KONG, for three years' service with possible extension. Salary £460, rising to £600 a year by annual increments of £20, payable locally, in dollars, at the Government rate of exchange, which is at present fixed at 2s. to the dollar. In addition, a strictly temporary exchange allowance of 20% of salary is at present paid, and thus at the present time the annual salary in dollars will be $5520 a year. The current rate of exchange being now about 2s. 4d. to the dollar the sterling equivalent of $5520 is accordingly about £640. No income tax. Free passages. Candidates, unmarried, aged 24-28, must be regularly trained Civil Engineers and have passed the Institution of Civil Engineers' examination, qualifying for Associate Membership or have obtained an exempting degree. Must be good draughtsman, well up in levelling, land and marine surveying, having some experience in the design, construction and maintenance of quay walls and piers.—Apply, at once, by letter, stating age, qualifications and experience to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W.1, quoting M/13425. H 455

Electrical Draughtsman

REQUIRED with experience in barrel and contactor controllers.—Apply, stating age, salary and experience, to HARLAND & WOLFF, LTD., Belfast. H 446

Draughtsmen Wanted by

West of England Firm manufacturing high-class small machinery, chiefly relating to printing and cardboard box manufacture. Previous experience in this class of work not essential, but applicants will be required to give evidence of ingenuity and practical engineering ability. Applications, which should give age (preferably 20-30), training and salary desired, will be treated in confidence.—Address, H 459, Offices of ENGINEERING.

THE MARCONI WIRELESS-BEAM REFLECTOR ON INCHKEITH.

By N. WELLS, M.Sc.

THE revolving wireless-beam reflector erected on Inchkeith Island, in the Firth of Forth, though novel is by no means the first of its kind. Even on Inchkeith, an early wooden model was erected, in the autumn of 1920, and a series of experiments was carried out, which proved the system to be a valuable aid to navigation. It was because of the satisfactory nature of the results obtained that the Marconi Company decided to erect the present steel structure, following closely the lines of a permanent commercial installation. Before this, much useful work had been accomplished in Italy and at Carnarvon, and an interesting and concise survey, which covers subsequent research, will be found in a paper read by Mr. C. S. Franklin before the Institution of Electrical Engineers on May 3, 1922. The purpose of the present article is to describe the existing reflector in more detail than has so far been made public. The plant has been working without a single hitch at regular intervals during the past 18 months.

The installation is at the north extremity of Inchkeith, about 50 ft. above mean tide level. The beam has a clear sweep of the navigable channel of the Forth from the east and round the island into Leith Harbour. South of the reflector the ground gradually rises to a height of 160 ft., and a hut containing the main wireless plant stands about 40 ft. back on this side. Early in 1921, plans were drawn out for a steel-built reflector, and in September the material began to reach Inchkeith. By the end of October, the structure was practically completed; but in a design so novel there were unavoidable faults, both of design and manufacture, which could only be rectified on the spot as need arose. The completion of the structure was followed by a long period of experimental work, in the course of which numerous reflector systems were built up, adjusted, tested and taken down; the wave-length was altered, and various circuits tried out, all in order to secure a harmonious system capable of working under every condition of weather and of producing a sharp, balanced and stable radio beam. Finally, during the summer of 1922, the installation reached a satisfactory state, followed by an official and entirely successful demonstration in November.

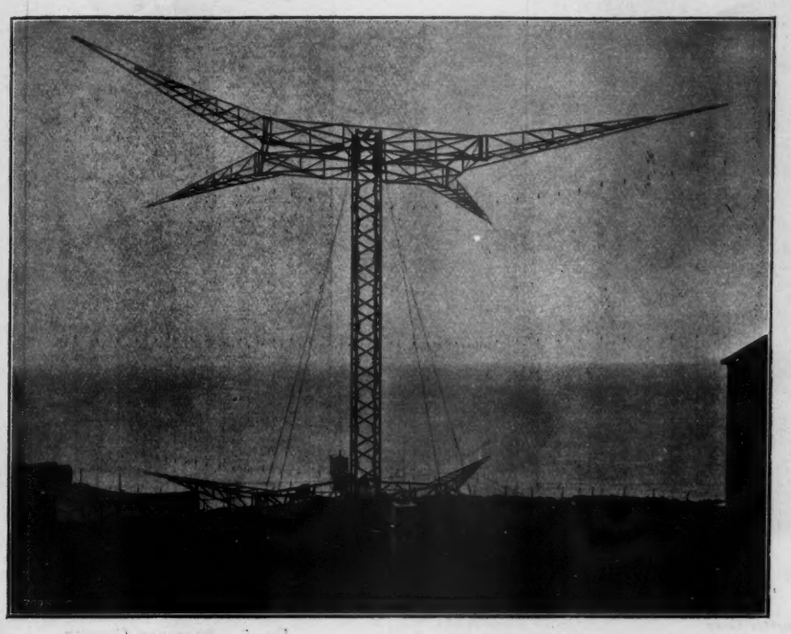


FIG. 1. GENERAL VIEW OF THE REFLECTOR.

FIG. 2. DRIVING GEAR.

The principle of the reflector is based on the fact that the electro-magnetic waves employed in radio transmission obey all the known laws of light. It is purely a question of wave-length that determines the dimensions of a reflecting system, and again purely the mechanical limits that determine the band of wave-lengths available for commercial use. For a revolving reflector, the limit is obviously a few metres only, and at Inchkeith the actual wave-lengths varied from 4·25 m. to 6·25 m. A cylindrical parabolic reflecting surface is built up of tuned wires, and the transmitter aerial, which is placed at the focus, takes the form of a plain suspended wire of half wave-length dimensions. The reflector wires are anchored by insulators at each end, and are plain, straight wires bearing a definite relation to the wave-length. In the case of the highly-damped waves employed at Inchkeith, there is a modifying factor in respect of extra radiation. The actual spacing of the wires has been largely a question of experiment, and the whole system was carefully checked and adjusted by a series of standard tests. It will be noticed from the general view of the reflector given in Fig. 1, that, in its parabolic form, the Marconi reflector comprises two or more elements for each reflecting system, a feature which, under certain conditions, greatly increases the total energy enveloped and reflected. At Inchkeith this amounts to nearly twice the energy with double-element, as compared with single-element, reflector wires.

In practice, there are two reflectors, symmetrically placed back to back, and built up on a girder frame or six-sided platform. Cast-iron runner wheels with steel tyres are located at the six corners and support the weight, the whole revolving on a circular rail track bedded in a concrete curb. There is a central telescopic bearing the under-member or shoe of which is bolted to a concrete block. The platform supports a lattice tower 32 ft. high, and this again supports, at its extremity, an upper frame or gallows. Both upper and lower frames are fitted with two pairs of arms, permanently stayed in position, and the two systems of reflector curves are supported between the upper and lower pairs of arms. At the base of the tower there are slip rings permitting the two rotating transmitter units to be connected by means of cables to the source of high-frequency supply.

The complete structure is symmetrical about a vertical axis, so that wind pressure is balanced and a uniform driving torque ensured when the system rotates. The sweep of the Inchkeith reflector is 31 ft. 9 in. from centre to extremity of an arm; the aperture, or distance from tip to tip between each pair of arms, is 43 ft., while the height from ground level totals 36 ft. It should be mentioned that the structure has withstood one of the most severe gales occurring during the past twenty years. The reflector is rotated by means of a large-diameter channel ring built into the underside of the lower platform. Horizontal radial steel pins are fitted in this ring, pitched to register with a pinion which is driven by an electric motor through worm gearing.

Automatic signalling is arranged for as follows: A flat, vertical metal band encircles the driving channel and carries 62 groups of marking plates, corresponding to the code of signals adopted. These engage the triggers of two stationary contact breakers connected with the two transmitting systems. Fig. 2 depicts the driving gear, one contact-breaker and a segment of the band, the marking plates being easily distinguished. Fig. 3 illustrates the code at present employed, which is, of course, arbitrary, while in Fig. 4 the automatic signalling arrangements are illustrated diagrammatically.

The structure revolves once in two minutes. As

THE MARCONI WIRELESS-BEAM REFLECTOR ON INCHKEITH.

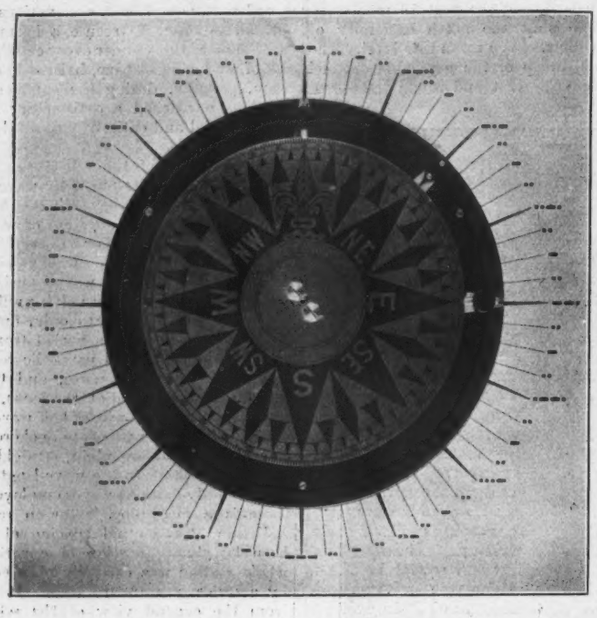


FIG. 3. SIGNALLING CODE.

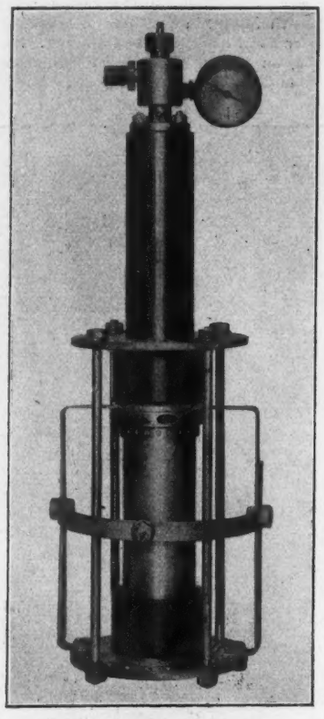
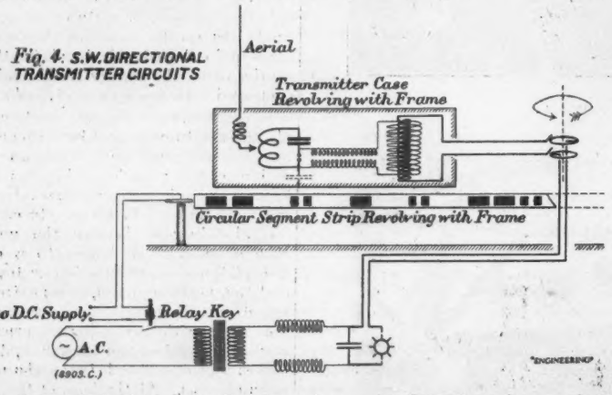


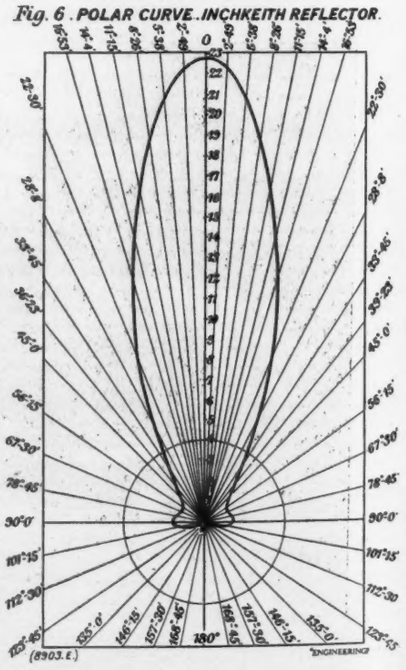
FIG. 5. PRESSURE CIRCUIT.



there are two reflectors facing in opposite directions, two beams separated by 180 deg. are projected. It follows that signals indicating the direction of ship to station will be received at intervals of one minute. The accuracy of direction is in no way dependent upon maintaining a constant period of rotation, and no special apparatus is installed, nor are special precautions adopted, beyond care to ensure that the machinery runs with reasonable uniformity. The rate of revolution of the reflector governs the rate at which the Morse signals are transmitted, and this works out at about 10 words per minute. Such sending can be read comfortably by an intelligent person without special training; in fact, the whole object of the system is to give guiding signals directly to the navigating officer, in the most straightforward manner possible and without employing an intermediary wireless operator.

The power-supply installation comprises a 4·5-kw. four-cylinder Austin and E.C.C. combination, and two Marconi ½-kw. synchronous-spark converters, together with the necessary transformers, condensers, feed chokes, relay keys, and minor parts for the circuits employed. The system is, briefly, that of two-stage high-frequency conversion, and is outlined in Fig. 4, where, for clearness, only the circuits involved in one transmitter are given. The converter forms the E.M.F. in an ordinary high-frequency, synchronous-spark system; the only peculiarity, and this should be mentioned, is that the supply cables from the hut to the reflector form part of the first high-frequency inductance, which is completed in the primary winding of a Tesla transformer placed in the transmitter case. The latter encloses the transformer and the short-wave circuit, together with the coupling to the aerial, which issues through an insulator in the roof of the case. The Tesla transformer steps up to about 60,000 volts high frequency, and in turn charges the extra high-frequency or short-wave circuit. This apparatus, known as the pressure circuit, is indicated in Fig. 5, and is a compact unit, designed by Mr. C. S. Franklin as the result of a long series of experiments. It has proved both reliable and durable.

Briefly described, the pressure circuit consists of a condenser of about 100 cm. capacity and a fixed gap built up in a cylindrical chamber which is under an air pressure of some 500 lb. per square inch. Owing to the corresponding increase in the dielectric strength of air with pressure, it follows that the condenser elements may be close and yet charged to a high potential difference. Similarly, the gap, for a given pressure and electric potential, may be set much closer than would be possible if the electrodes were in air at atmospheric pressure; the effect of this is to reduce damping considerably. Parallel inductance wings are outside, and their dimensions will surprise those who are accustomed only to normal wave-lengths; the wings are adjustable either horizontally or vertically for the purpose of tuning. The pressure circuit is connected to the aerial by an adjustable coupling strap, to be seen in Fig. 5. An intermediate tuning coil ensures correct



energy distribution along the half-wave aerial, while the system has a definite capacity to earth about the metal base of the pressure circuit.

Describing the application of the reflector, it is necessary first to realise that wireless energy is propagated in the form of a vertically polarised beam, and a very fair representation of the shape and strength of the beam at a distance of 2 nautical miles is given in the polar curve shown in Fig. 6, which indicates the strength of signals, measured in volts at the receiver, as the beam points in successive

THE MARCONI WIRELESS-BEAM REFLECTOR ON INCHKEITH.

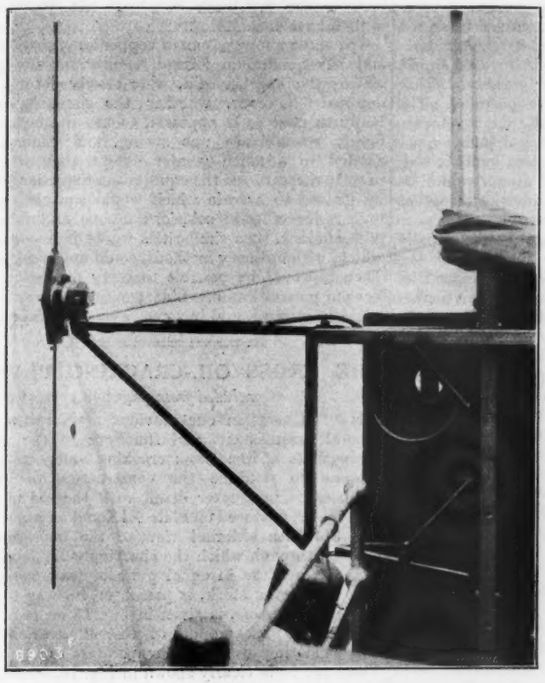


FIG. 7. RECEIVING AERIAL ON S.S. "ROYAL SCOT."

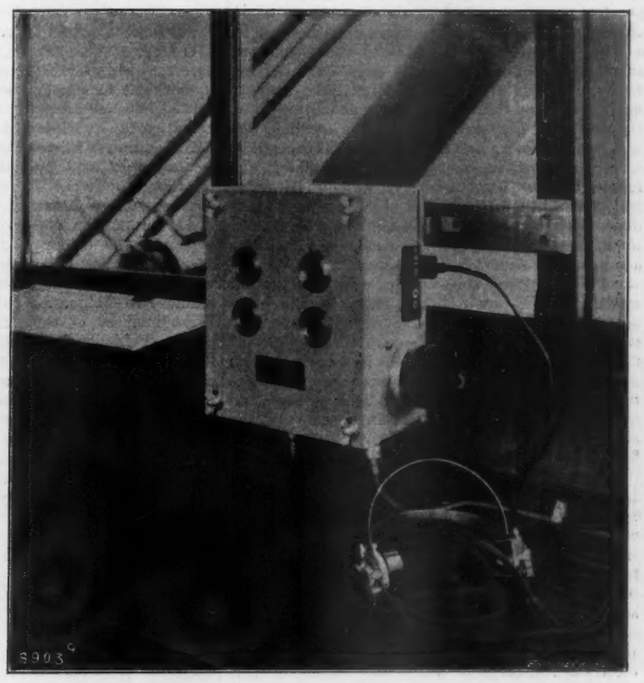


FIG. 8. RECEIVING SET ON S.S. "ROYAL SCOT."

angles through 360 deg. For the purpose of plotting this curve the rotating mechanism was controlled by an attendant and a series of V's sent with the beam pointing in the directions indicated. The symmetry is particularly noticeable.

It will be understood that when the reflector rotates continuously, beam signals are transmitted as the axis passes through each half point of the compass. Let us suppose that 20 signals are audible at the receiver. Then, owing to the symmetry of the beam, the bearing of the beam axis will lie between the tenth and eleventh, *i.e.* the loudest signals. In practice, however, the bearing is determined by noting the first and last signals heard, when midway between the two corresponding bearings will lie that of the beam axis. In conjunction with the receiver, a compass dial is provided fitted with simple dividing arms as shown in Fig. 3, so that if one arm is moved to register with the first signal heard and the other arm to register with the last signal, a pointer automatically divides the angle enclosed by these two arms, thus indicating the bearing of ship to station. It is better to limit the audible arc to less than 20 signals, by de-coupling or otherwise reducing signal strength at the receiver.

When an approaching vessel is equipped with a beam receiver, it is clear that at the working limit of range only two or three signals will be heard each minute; as the distance between ship and station is reduced, the audible arc increases, and five or six signals are heard, corresponding to a beam sweep of about 10 deg. Closer in still, signals will increase greatly in strength, and the audible arc be much wider, but, by employing the de-coupling handle on the receiver, the number of signals may be limited to, say, ten. Since the bearing is always the mean of the first and last signals, accuracy is maintained from the furthest distance out to right close up. Compensation may be made for any difference in strength as judged between the first and last signals.

In connection with reception of the signals, a brief description may be given of the beam receiver as fitted to the "Royal Scot," a vessel sailing between Leith and London. She is of 1,726 gross tonnage and 6,000 indicated horse-power, and is owned by the London and Edinburgh Shipping Co., Limited. The installation consists of two aerial units fixed 6 ft. out on light brackets from the port and starboard sides of the bridge. One of these is illustrated in Fig. 7. Each aerial unit comprises a waterproof cylindrical chamber 4 in. diam. by 3 in. long, supporting midway a vertical rod aerial approximately 7 ft. 6 in. in length; inside the chamber the aerial is coupled to a cable and this conveys the high-frequency signals to the receiver fitted in the wheel house. When the apparatus is not in commission, the brackets swing inwards, so keeping the aerial rods out of harm's way. The receiver is contained in a plain metal covered case, and there is an absence of complicated adjustments; in fact the entire control is effected by one disc-like handle. The apparatus is shown in Fig. 8. The circuit consists of two simple rectifiers coupled to the port and starboard aerials, a note magnifier and a signal limiting device. Tuning is fixed, and beyond switching on and limiting the number of signals heard, there are no adjustments. A slight turn of the handle switches on, while further motion cuts off, stop by stop, the number of incoming signals.

For accuracy, the number of signals heard should not exceed a total of 10, and for any one stop the limits are 5 minimum to 10 maximum, after which the handle is turned to another stop. The present range is 9 miles with Inchkeith astern, 10 miles with Inchkeith ahead.* Bearings are obtained to within an accuracy of $\frac{1}{4}$ point. Below is an abridged table giving distance, signals heard and position of handle. It is obvious that when the user is accustomed to a particular installation, the distance of ship to station can be gauged roughly by the stop and more accurately by the number of signals heard on that stop.

Range.	No. of Signals Heard.	Position of Handle.
10 Nautical miles ...	5	1st Stop.
8½ " " ...	7	" "
7 " " ...	9	" "
6 " " ...	10	" "
5 " " ...	8	2nd Stop.
3 " " ...	6	3rd "
1 " " ...	7	4th "
½ " " ...	9	5th "

* In connection with apparatus now being developed at South Foreland this range has already been greatly extended.

The writer's thanks are due to Mr. D. Stevenson, Engineer to the Northern Lighthouse Board, and to Messrs. Marconi's Wireless Telegraph Company, Limited, for information and permission to use the illustrations incorporated in this article.

THE INNER STRUCTURE OF ALLOYS.

THE third of the series of Cantor lectures on the above subject was delivered by Dr. Walter Rosenhain at the Royal Society of Arts on Monday of last week. The lecturer said that all were agreed that the conduction of electricity through metal took the form of a passage of electrons through the metal. If an electromotive force were applied to a conductor the effect at the far end would make itself felt after a time, measurable in terms of the velocity of light. The electrons, however, could not move through the metal at that rate. It was rather a question of a number of electrons being pushed in at one end and a corresponding number being pushed out at the other end, and it was the electrical stress which was transmitted with the velocity of light in some manner not yet known. An early idea was that the metal behaved, so far as the electrons were concerned, as if it were an empty space, but were this the case the specific heat of the metal would have to be far higher than experiment proved it to be. Lindemann had suggested that between the lattice of the crystal there was an independent lattice of electrons, but it had been shown that such an electron lattice would be unstable. The fact, nevertheless, remained that the electrons must in some way or other communicate their motion through the crystals of the metal, suggesting that where the crystals of a metal consisted of atoms regularly arranged in a lattice, the passage of the electrons through that lattice—either through the atoms or between them, as the case might be—should be very little if at all impeded by the atoms. If, however, the atoms were not in line, either through thermal oscillations or through distortion of the lattice, the motion of an electron would be impeded and a part of its energy would be dissipated as heat. Taking atoms of pure metal in perfectly arranged crystals and free from thermal oscillations, no resistance to the passage of the

electrons would be expected. As Kammerlingh-Onnes had shown in the case of pure lead, when a temperature of not more than 5 or 6 deg. above absolute zero was reached the resistance to electrical current became zero. A current, once started, in a ring of lead at that temperature would continue substantially undiminished for days and even for weeks. If that theory were the whole story it might be assumed that this result would follow in the case of all pure metals, but not in an alloy. It occurred, however, only in certain metals occupying a certain position in the periodic table. It followed that there must accordingly be some resistance to the passage of the electrons which was dependent upon the nature of the atom, or, rather, upon the nature of interatomic linkage, in some arrangement of which the passage was free and super-conductivity became possible. In other arrangements it was not free, and a certain dissipation of energy occurred even when thermal-oscillation was practically absent. If at any instant there was a certain row of atoms in a crystal which was truly in line and that line offered no resistance to electrical conduction, the row of atoms could carry as much current as was desired. The material then behaved as a super-conductor, in spite of some other rows of atoms being slightly displaced.

This conception of the distortion of the atomic lattice by thermal oscillation accounted for the behaviour of metals, their conductivity at very low temperatures and the rapid diminution of conductivity with rise of temperature, the rows of atoms being increasingly distorted by thermal oscillation. The case was different with alloys. In a solid solution the effect of temperature in increasing the electrical resistance would be smaller than in a pure metal, and alloys had been produced the electrical resistance of which was almost independent of the temperature.

Incidentally, the lecturer mentioned that it was not only an electrical impulse that produced heat by dissipation of energy when passing through a row of atoms if the row were not perfectly straight. A mechanical impulse might have the same effect. Thus if a load were applied to a piece of metal the stress was transmitted through the metal as an elastic wave. If the atoms were perfectly in line, the transmission of energy would be expected to take place free from dissipation. If not perfectly regular, a certain amount of vibration would be set up in the rows of atoms by the wave passing through them, with resulting elastic hysteresis. Taking a load on and off dissipated therefore a certain amount of energy, in spite of the fact that there was no permanent change of dimensions.

Thus far the lecturer had considered the atom as a rigid and indivisible whole. Actually the atom was, he said, a complex system of electrons revolving about a nucleus. It could, in fact, be distorted and mechanically compressed to a much smaller size; and the centres of the atoms could also be forced closer together. There must be some linkage by which the cohesive forces acted. If an atom were pushed out of its normal position, it was evident that wherever in the complex system the forces acted, they would not merely displace the atom, but must also to a certain extent disturb the atom itself. The effect, then, of pushing an atom out of its position must be to displace the electron orbits in the atom, though possibly only the outer ones.

The theory of radiation had shown that electrons were capable of jumping from one orbit to another, and in doing so gave out radiant energy of definite wave-lengths. When radiation fell upon the atom the latter was capable of absorbing the same kind of rays as it would radiate if excited, absorbing thus certain particular frequencies, with the result that the light reflected from a crystal composed of such atoms would have a definite colour. In metals colour was not, as a rule, marked, the selective absorption of the atoms not being very pronounced: studied closely, however, they had distinctive colours. Copper and gold, for instance, as a result of absorption of blue waves, were strongly coloured. If atoms of this kind were in any way distorted, a change in the colour of the material might be expected. Colour was an attribute of metals less studied than others. The problem of colour was to some extent cleared up by the theory of lattice-distortion, with a consequent slight atomic distortion. To a strongly coloured metal like copper, 50 per cent. or 60 per cent. of zinc might be added before the copper colour would become approximately white, whereas 15 per cent. of nickel would be sufficient to change the colour entirely. Other metals produced effects in other proportions. The distortion theory explained some of the phenomena.

The adding of zinc to the lattice of pure copper served to expand and distort the lattice, and, according to theory, the copper atoms would be correspondingly distorted to an increasing extent as the proportion of solute increased. As a consequence, the colour of the copper was rapidly changed, coming down, near to the limit of the solid solution, to a greenish yellow—typical of ordinary 70–30 brass. What happened with a further slight increase of the zinc content? The alpha lattice could not be further distorted, and a new lattice was formed. Probably nickel compressed the copper lattice, whereas zinc expanded it. When distortion was accompanied by compression of the lattice, the effect on electrical resistance was generally much greater than in the case of an expansion of the lattice. Contraction seemed to have a much greater effect on the physical properties.

Magnetism was a mysterious property, and modern views suggested that it was due to, or accompanied by, a certain want of symmetry in the atom itself. If that were so, it would be easy to understand that any distortion of the atom, as the result of lattice distortion, must have a disproportionately large effect upon the magnetic behaviour of the material. Plastic strain produced profound changes in magnetic materials. The magnetic properties of soft iron transformer sheet could be seriously injured by applying a certain amount of cold work; the effect on the magnetic properties was far greater than that on the mechanical properties. The effect of alloying atoms might either improve or deteriorate the magnetic properties, depending on the atoms introduced. If, in the case of commercial iron, atoms of aluminium in solid solution were introduced into the lattice, the magnetic properties and permeability were improved and hysteresis loss was diminished; probably because in that iron a sufficient number of injurious atoms were present to produce a certain degree of initial distortion; and when these other atoms, whose direction of distortion was opposed to that of those already present, were added, they might relieve the total distortion of the lattice, and, therefore, that of the atoms.

After referring to "permalloy," the copper-nickel and other systems, Dr. Rosenhain exhibited diagrams relating to the copper-aluminium compound $CuAl_2$ from which, among other things, it appeared that the aluminium atom absorbed something—presumably electrons—from the copper atoms and reduced their effective size, leading them to come much closer together. Obviously a copper atom could not be replaced by an aluminium atom and retain the original arrangement. Generally, when an intermetallic compound passed into solid solution he believed it would be right to say that it did so in the form of dissociated individual atoms. Sometimes, as in the copper-zinc system, a system was obtained in which there was a succession of solid solutions. The idea had long been held that these were, in reality, intermetallic compounds capable of dissolving both zinc and copper. The continuous ranges, however, suggested that these were not intermetallic compounds at all, but rather what he would call "allotropic lattices." The normal lattice was not necessarily the only lattice in which the atom could be arranged. So long as the energy conditions permitted, additional atoms of zinc replacing copper were simply built on to the same face-centred lattice. When the number of zinc atoms increased beyond a certain amount, the copper atoms changed over into a different lattice arrangement, upon which they could accommodate a larger number of zinc atoms. That lattice was really an allotropic form of copper kept in position by the number of zinc atoms. Further increases of zinc led to the formation of other lattices, until, at the end of the system, the lattice of zinc itself was formed. None of the lattices was due to the formation of any definite compound, but merely to a mutual arrangement between the two kinds of atoms—not uncommon in metal systems.

The three alloy systems of copper-zinc, silver-zinc and silver-cadmium formed equilibrium diagrams which, the speaker said, were closely alike. He doubted, however, whether the similarity was really as close as it appeared to be, although the family resemblance was strong, and similarities existed to a much greater extent than was at present realised. If the equilibrium diagrams could be plotted to a scale which would squeeze out a long range of solid solutions in one and expand it in another, then similarities would be recognised which, with ordinary methods, could not be plotted. Then it would be possible to carry prediction far beyond present limits. Binary and ternary systems could be studied, and in some cases quaternary.

THE CROSS OIL-CRACKING PLANT.

(*Concluded from page* 249.)

HAVING dealt in our previous article with the general arrangement and functions of the main components of the Cross cracking units, we now propose to describe the construction of these components in greater detail with the aid of the drawings reproduced on Plate XIX and on pages 313 and 314. An external view of the two tubular heaters, through which the charging stock, consisting of a mixture in equal parts of fresh kerosene and re-charging stock, is passed on its way to the reaction chambers, is given in Fig. 15 on page 324 and in the background of this illustration the dephlegmating towers and evaporators can be seen. These are more clearly shown in Fig. 16, which is a general view of the two units from the control-house end. The outlet ends of the two reaction chambers are visible in this illustration just above the control-house roof, but they are shown more clearly in Figs. 17 and 18, which also show the dephlegmating towers and evaporators on a larger scale. Figs. 9 and 10 on Plate XVI, published with our issue of February 27 last, may be examined in connection with the photographic illustrations on page 324 and these will help to make the arrangements clear.

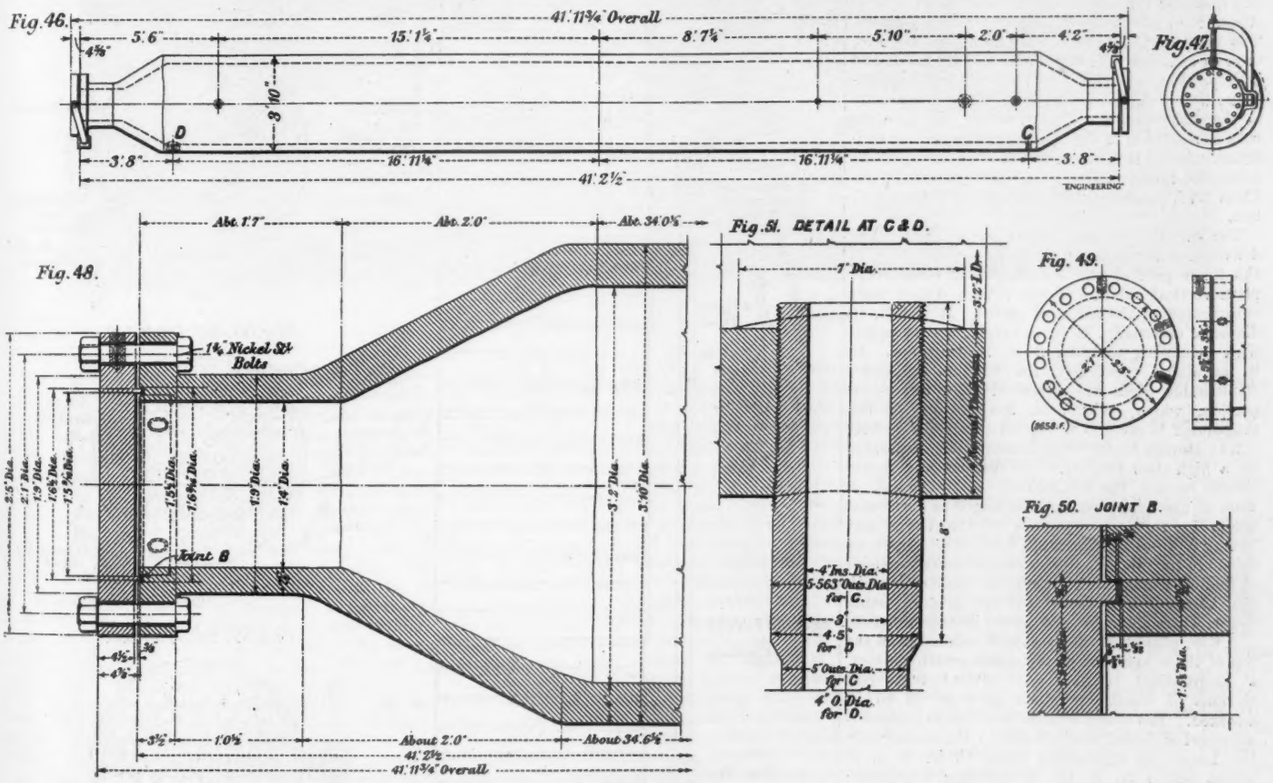
It will be logical first to describe the tubular heater, the design and construction of which can be followed by studying the drawings reproduced in Figs. 19 to 35 on Plate XIX. The heater comprises two groups of horizontal tubes enclosed in a rectangular chamber of brickwork, lined with firebrick, and usually supported on each side, as shown in Figs. 19 and 20, by four buttresses into which are built channel-iron braces tied together at their upper ends by steel rods. Three rolled-steel joists, placed horizontally on each side, are provided to give intermediate support, the vertical channel braces bearing on these joists as will be understood from the illustrations referred to. Actually the buttresses were not built at the Medway plant, as will be evident from an examination of Fig. 15 on page 324, but in other respects the heaters were constructed in accordance with the drawings on Plate XIX. The dimensions are indicated in the figures in all cases, so that they need not be repeated here.

In the lower part of the brickwork casing, combustion chambers are formed by a perforated firebrick arch with a central wall of the same material. The burners which, as previously mentioned, are normally supplied with the non-condensable gases produced in the cracking process, are mounted at the outer ends of the combustion chambers in which the temperature maintained is of the order of 1500 deg. F. The arrangement of the combustion chambers is best shown in the longitudinal and transverse sections of the heater given in Figs. 23 and 24, but the plan, Fig. 27, shows the disposition of the perforations in the arch most clearly. Fig. 28 is a sectional plan of the central dividing wall of the combustion chamber, the wall being also shown in Fig. 23, while particulars of the special firebricks used for the construction of the arch are given in Fig. 31. The object of the perforated arch is, of course, to distribute the heat uniformly among the

tubes and to protect them from the highest flame temperatures.

As previously mentioned, the tubes are arranged in two groups, and from Figs. 23 and 24 it will be seen that the two groups are partially separated by a second firebrick arch, openings for the passage of the hot gases being left at each end. A plan of this upper arch is given in Fig. 26, and it will be noticed that this arch also contains a number of perforations which serve to distribute the gases more uniformly among the upper bank of tubes. The gases finally escape through a steel stack provided with a damper at the bottom, as shown in Fig. 23, the exit temperature of the gases being of the order of 625 deg. F. The tubes in the upper bank are described as preheater tubes, and the oil, or charging stock as it is called, enters them at the top of the heater at a temperature of about 300 deg. F., passing downwards through each tube in series and then flowing through a connecting pipe doubtless the fact will have been noticed already, that platforms are provided along the sides and ends of the heater casing to facilitate access to all important points. These platforms, and the ladders by which they are reached from the ground, are shown in Figs. 19 and 23, as well as in Fig. 15, on page 324. Another point to which attention may be drawn before leaving the heater, is that the tubes in the lower bank, *i.e.*, the cracking tubes, are supported at the middle of their length by beams of Fahrite heat-resisting alloy. These beams are shown in section in Fig. 23 on Plate XIX and in elevation in Fig. 24. The ends of the beams are supported on castings built into the brickwork, as shown in detail in Figs. 29 and 33. To facilitate the inspection of the interior of the heater when it is out of action, blind windows, closed with easily-removable brickwork, are provided in the sides and ends of the casing, as will be seen in Figs. 19 and 20. A section through one of these windows, which gives access to by a ring of copper placed in an annular recess in the flanged end of the chamber, a corresponding projection on the cover fitting into the recess as shown in Fig. 50. Davits are generally provided at each end to support the covers when the latter are removed for cleaning out the coke. The whole of the chamber, including the end covers, is carefully lagged, the average thickness of insulating material being about 5 in.

As mentioned in our previous article, on page 248 *ante*, the working pressure in the reaction chambers is about 700 lb. per square inch, but they were tested at a pressure of 10,000 lb. per sq. in. and were designed to give a factor of safety of 15 under working conditions. Moreover, each chamber is fitted with a 4-in. relief valve set to blow off at 900 lb. per square inch. The main outlet from the reaction chamber is through a reduction or throttling valve, from which the synthetic crude petroleum, as the charging stock has now become, is led through the



at one end to the bottom of the lower bank of tubes. These are known as cracking tubes, and the charging stock flows upwards through them, finally leaving at the top of the bank at a temperature of 900 deg. F. and passing into the reaction chamber. There are 45 tubes in each bank and all the tubes are 24 ft. in length, 3 in. in diameter internally, and ½ in. in thickness; hot-rolled seamless tubes are used for the preheater bank and cold-drawn seamless tubes for the cracking bank. The tubes are connected in series at their ends by special cast-steel return bends, into which they are secured by rolling and beading, with intervening ferrules of soft steel, as shown in Fig. 35. Details of the return bends are given in Fig. 34, from which it will be seen that a removable conical plug stopper is provided opposite the end of each tube to enable the latter to be cleaned out. This is usually done at the end of each run to maintain efficient heat transmission, although, owing to the high velocity of the oil in the tubes, the deposit in them is but slight. The coke, as previously mentioned, is deposited almost entirely in the reaction chamber. To give access to the ends of the tubes for cleaning, hinged insulated doors are provided at each end of the casing of the heater, these doors being shown in Figs. 19, 20, 23 and 26, while details of the door frames are given in Figs. 21 and 22. It may here be mentioned, although the space below the cracking tubes, is given in Fig. 32, and a sectional plan of the same part of the brickwork is reproduced in Fig. 30. Fig. 25 shows one of the pipe sleeves provided to accommodate a thermo-couple, which is connected to a recorder on the instrument board in the control house, giving a continuous record of the furnace temperature as mentioned on page 249, *ante*.

The heated charging stock is led from the heater to the reaction chamber through the horizontal lagged pipe visible towards the right of Fig. 15, on page 324. A plan and end elevation of the reaction chamber for one cracking unit are given in Figs. 46 and 47, respectively, on this page, while details of the ends and of a 4-in. pipe connection for a relief valve are reproduced in Figs. 48 to 51. Apart from their importance in the cracking process, the reaction chambers, which were made by Messrs. John Brown and Co., Limited, at Sheffield, are of considerable interest to engineers, since each consists of a single steel forging, 41 ft. 2½ in. in length, 3 ft. 10 in. in diameter, 4 in. in thickness, and weighing about 35 tons. The ends are coned down as shown, to form a cylindrical portion 1 ft. 4 in. in diameter, and 2½ in. thick, which is flanged and covered by a steel disc 2 ft. 5 in. in diameter and 4½ in. thick. The covers are retained in position by 16—1¼-in. nickel-steel bolts, a joint being made re-boiler in the bottom of the dephlegmating tower to the evaporator. The valve and its connections are visible in the half-tone engravings, Figs. 17 and 18, on page 324, but the arrangements are more clearly illustrated in Fig. 36 on Plate XIX. Drawings of the valve itself are reproduced in Figs. 37 to 40, from which its dimensions can be obtained. It consists simply of a forged steel rectangular body with a cover of the same material secured by studs. The valve proper consists of a rectangular block of steel, which is adjusted by a screwed stem passing through a stuffing-box and working in a nut formed in a cast-steel yoke, as will be clear from the illustrations. As explained in our previous article, the adjustment of the valve, in conjunction with the control of the speed of the pumps, forms the principal means of regulating both the pressure and temperature in the reaction chamber, and is, therefore, of the utmost importance in the working of the cracking process. For this reason, the valve stem is extended downwards through the roof of the control-house, terminating in a large handwheel located in a convenient position at the side of the instrument board.

The greater part of the coke which is deposited in the reaction chambers collects towards the outlet end, and is, therefore, liable to choke the connection to the reduction valve. It is, of course,

essential to keep this connection clear, and, for this reason, the cleaning device shown in Fig. 36, and illustrated in detail in Figs. 41 to 45, is provided. It consists, as will be seen, of a form of auger having a long stem which extends outwards through a stuffing-box, and is attached to a screw. The screw passes through a split nut mounted in a steel frame, so that, by turning the handle, the auger can be rotated and moved forwards through the reduction valve and into the reaction chamber in order to clear the passage. This operation can be carried out at intervals without interfering with the working of the process.

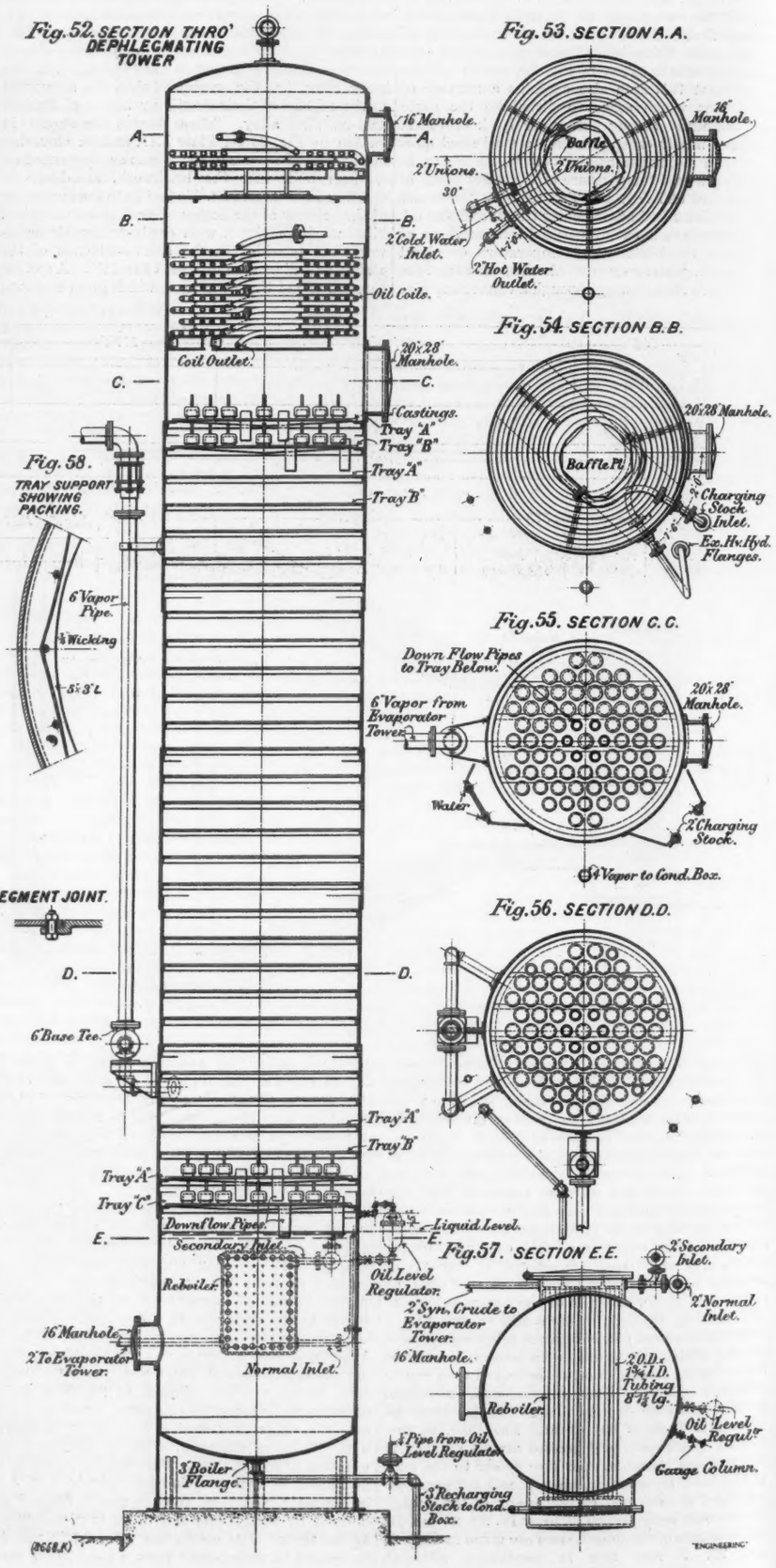
It is this deposition of coke in the reaction chamber which determines the length of run possible with the process, and, when using kerosene, it is usually necessary to shut down the plant for cleaning purposes at intervals of about 15 days. Before cleaning out the reaction chambers they are steamed to assist in loosening the coke and to remove any fumes or vapours before the men enter; special steam connections are provided for this purpose. The coke, of which there may be about 4,500 lb. in each chamber, has to be removed by hand, and is dropped from the inlet ends directly into hoppers, under which wagons are placed. The arrangements at the outlet ends are similar, except that here the coke first falls on to the concrete roof of the control-house, whence it is raked into a hopper, as will be understood on reference to Figs. 9 and 10 on Plate XVI, published with our issue of February 27 last.

The evaporator, into which the cracked oil is delivered after passing through the re-boiler in the lower part of the dephlegmating tower, is a plain vertical cylindrical vessel with dished ends constructed of riveted steel plates. It is 6 ft. in diameter externally, 40 ft. in height, and is lagged with insulating material 2 in. in thickness. In it, as stated previously, the vapours and non-condensable gases are separated from the liquid portion, which collects in the bottom of the evaporator tower and is run off through a cooling coil to storage tanks, being subsequently disposable as a high-class fuel oil. The vapour and gases, before leaving the evaporator, pass through a mass of fine expanded metal arranged in horizontal layers in the upper portion of the tower and having a total thickness of 6 ft. The object of this is to trap and retain any finely-divided particles of fuel oil which might otherwise pass over with the vapours and gases to the dephlegmating tower, where their presence would be objectionable.

A 6-in. pipe leads the gases and vapours from the top of the evaporator to the dephlegmating tower, a longitudinal section and several transverse sections of which are given in Figs. 52 to 57 annexed. The tower consists of a vertical cylindrical vessel of riveted steel, similar to the evaporator, but larger, its dimensions being 52 ft. 6 in. in height and 7 ft. 4½ in. in diameter internally; it is also covered with a 2-in. coating of heat-insulating material. In the bottom of the tower the re-boiler, referred to on page 249 *ante*, is located, as shown in the longitudinal section, Fig. 52, and above this is placed a series of 30 cast-iron "bubble" trays, each tray being supported on an angle ring riveted to the shell. The gases and vapours from the evaporator enter the tower between the 5th and 6th trays from the bottom, passing upwards through the trays, as will be explained later, together with the vapour from the re-charging stock collected in the bottom of the tower and heated by the re-boiler. The latter consists of a bank of 80 tubes, 1¾ in. in internal diameter, expanded into cast-iron headers, clearly shown in Fig. 57. As indicated by dotted lines in this figure, the headers are arranged so as to divide the tubes into groups in series, through which the hot oil and vapours from the reaction chamber pass on their way to the evaporator.

The bubble trays, which rest on rings of packing material indicated in Fig. 58, are formed with a number of short vertical pipes, the upper ends of which are covered by inverted cups having serrated edges. The edges of these cups dip below the surface of the condensed vapours which collect on the trays when the plant is in operation, the

DEPHLEGMATING TOWER; CROSS CRACKING PLANT.



CROSS OIL-CRACKING PLANT ON THE MEDWAY.

FIG. 58. FILLING STATION FOR ROAD VEHICLES.

level of the liquid being determined by overflow pipes shown in Fig. 52. Except for differences in the disposition of these overflow pipes, the whole of the trays are identical, although only those at the top and bottom of the series are drawn in detail in Fig. 52; plans of the two forms of tray used are given in Figs. 55 and 56. It will be understood that, with the arrangement described, the vapour, and gases travel upwards, bubbling through the liquid retained on the trays and being gradually cooled and partly condensed as they rise. The liquid, on the other hand, travels downwards, its temperature rising as it descends, owing to the passage through it of the hot gases and vapours, until it finally collects in the bottom of the towers where it is subjected to the heating effect of the re-boiler. The latter maintains the liquid at a temperature of about 665 deg. F., so that any constituents boiling at this, or at lower, temperatures are evaporated. The liquid, which is known as recharging stock, is run off through a cooling coil to storage, and is afterwards passed through the cracking plant for further treatment with an equal proportion of fresh kerosene. An automatic regulator is provided, as indicated by dotted lines in Fig. 52, to maintain the re-charging stock in the tower at a constant level.

The gases and vapours, after passing through the uppermost tray of the series, come into contact with a coil of piping through which the cold charging stock flows on its way to the tubular heater. The charging stock is thereby heated and the gases and vapours cooled, further cooling of the latter being effected by another coil of piping through which cold water is circulated. The two coils are shown in Figs. 52, 53 and 54, and, by regulating the flow through them, the temperature of the upper part of the tower can be maintained at the desired value, viz., about 300 deg. F. Due allowance being made for the fact that the pressure in the tower is about 20 lb. per square inch, the temperature mentioned will be the final boiling-point of the petrol produced, since the constituents boiling at higher temperatures will be condensed and retained in the tower. Both the dephlegmating towers and the evaporators for the Medway plant were constructed by Messrs. Aveling and Porter, Limited, of Rochester.

The gases and vapours leaving the top of the dephlegmating tower are passed through a cooling coil which, together with those referred to above, are located in open water tanks at the sides of the plant, as is most clearly shown in Figs. 9 and 10 on Plate XVI *ante*. In the coils, the vapours are condensed, the liquid petrol thus produced passing on with the non-condensable gases to the gas separators shown on the extreme right of the two figures just referred to. These separators are plain cylindrical vessels of riveted steel mounted vertically and measuring 4 ft. in diameter internally and 16 ft. in height. They are fitted with relief valves and with a device for maintaining the petrol at a constant level. The gas is conducted away from the tops of the separators to the Benwick plant, in which any petrol vapour present is recovered, the remaining gas being used in the burners of the tubular heaters as well as for heating purposes in other parts of the plant. The petrol, which at this stage is a clear water-white liquid, is run from the separators into storage tanks, and can be used in this condition. It is, however, subjected to treatment with sulphuric acid and caustic soda in a plant involving redistillation, in order to remove the characteristic odour and also to eliminate all traces of gum-forming substances which might give trouble from deposits in the cylinders of internal-combustion engines.

At its present capacity the annual production of the plant would be about 8,000,000 gallons of refined spirit, which is sold under the trade name "Power Petrol," and is distributed by the Power Petroleum Co., Ltd. Three methods of distribution in bulk are employed for this "Power Petrol," the spirit being loaded into tank vessels at the pier, illustrated on page 248 *ante*, into 3,600 gallon tank wagons for railway transport, or into Saurer lorries for transport by road. At the filling station for road vehicles, which is illustrated in Fig. 58 above, four cylindrical tanks, each having a capacity of 10,000 gallons, are mounted on a steel staging at a height of 20 ft. above the ground level, two of the tanks being used for petrol and one each for kerosene and fuel oil. There are two sets of filling pipes for each of the three fuels, one being visible on the extreme left of Fig. 58 and the other being located over the lorry seen in the foreground. This lorry is a six-wheeled vehicle on which is mounted a cylindrical tank having three compartments with an aggregate capacity of 2,000 gallons; four-wheeled lorries, carrying 1,000-gallon tanks, are also used for distribution by road.

In view of the comparative novelty of the plant, as far as this country is concerned, it may be of interest to give a few particulars as to the quality of the main product. Generally it may be stated that Power petrol complies, in all respects, with the requirements of the British Engineering Standards Association specification A for motor spirit. The distillation chart of a commercial sample indicates that it has an initial boiling point of 35 deg. C. and a final boiling point of 173·9 deg. C., the temperatures at which 20 per cent., 50 per cent., and 80 per cent. of the total have been distilled over being 85·7 deg., 130 deg., and 157·2 deg. C. The A specification for motor spirit requires that the temperature at which the first drop distils over shall not exceed 55 deg. C.; that when 20 per cent. by volume of the distillate has been collected the temperature shall not exceed 105 deg. C.; and that the whole of the liquid shall have distilled when the temperature reaches 225 deg. C. Probably the most important characteristic of Power petrol is its anti-detonating quality, which arises from the presence of a comparatively high proportion of aromatics, viz., about 22 per cent. This enables a higher compression ratio to be used than would be possible with ordinary grade A spirit unless the latter were blended with benzol.

Tests carried out by Mr. H. Ricardo indicate that the highest compression ratio that can be usefully employed with Power petrol is 5·79 to 1, and it should be pointed out that this ratio is not necessarily that at which audible detonation commences, but that at which no increase of power results from raising the compression ratio further. The figure given compares very favourably with that for unblended grade A spirit, which would be of the order of 4·75 to 1. Comparative consumption tests have also been made on the Ricardo experimental engine with Power petrol and a motor spirit free from aromatics. The compression ratio used throughout these tests was 4·5 to 1, and the minimum fuel consumptions obtained were 0·458 pint per indicated horse-power hour with Power petrol, and 0·475 pint per indicated horse-power hour with the other spirit; with the higher

SPRING TESTING MACHINE.

CONSTRUCTED BY MESSRS. W. AND T. AVERY, LIMITED, ENGINEERS, BIRMINGHAM.

(*For Description, see opposite Page.*)

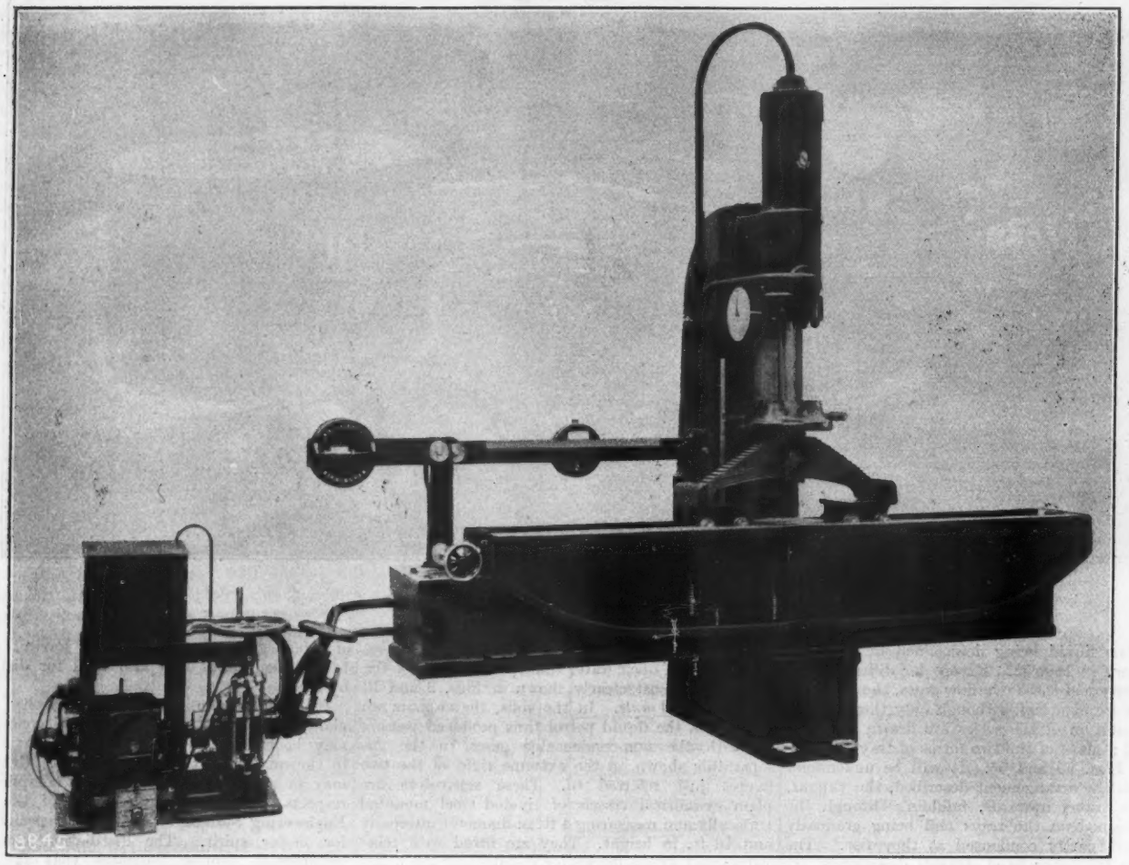


FIG. 1.

compression ratio possible with the former the difference would, of course, have been still greater. Further tests, we understand, are now in progress to determine the suitability of Power petrol for aviation purposes, but the results of these are not yet available. Enough has probably been said, however, to indicate that the Cross process is capable of producing a very useful fuel for motor vehicles, and now affords an interesting and important means of transforming heavy oils into a form in which they are of greater value to the community. In the future, if the demand for motor spirit increases—as appears likely to be the case—such means will proably have to be relied upon as a source of supply to an even greater extent than is now the case, although we understand that rather more than one-third of the present consumption of motor spirit in the United States is produced by cracking processes.

In conclusion, we should mention that while the the M. W. Kellogg Company, of New York, are now responsible for the technical and commercial development of the Cross process, as stated on page 247 *ante*, the patents of the process are owned by the Gasoline Products Company, Inc., of New York, and the cracking plant of the Medway Oil and Storage Company, Limited, was constructed and installed under the supervision of Messrs. Heron Rogers and Pettit, of Bridge House, 181, Queen Victoria-street, E.C.4, as consulting engineers to the Medway Company, to designs supplied by the Cross-Widdell Engineering Company, Inc., of Kansas City, the designs being slightly modified to suit the conditions prevailing in this country. Messrs. Heron Rogers and Pettit were responsible for the construction and erection of the main plant including the refinery, harbour, tanks, distributing system, &c., as well as for the general design. The design of the plant and steam still for treating the cracked spirit was due to Mr. F. C. Koch, the chief engineer of the Medway Company.

THE IRON AND STEEL INDUSTRY.

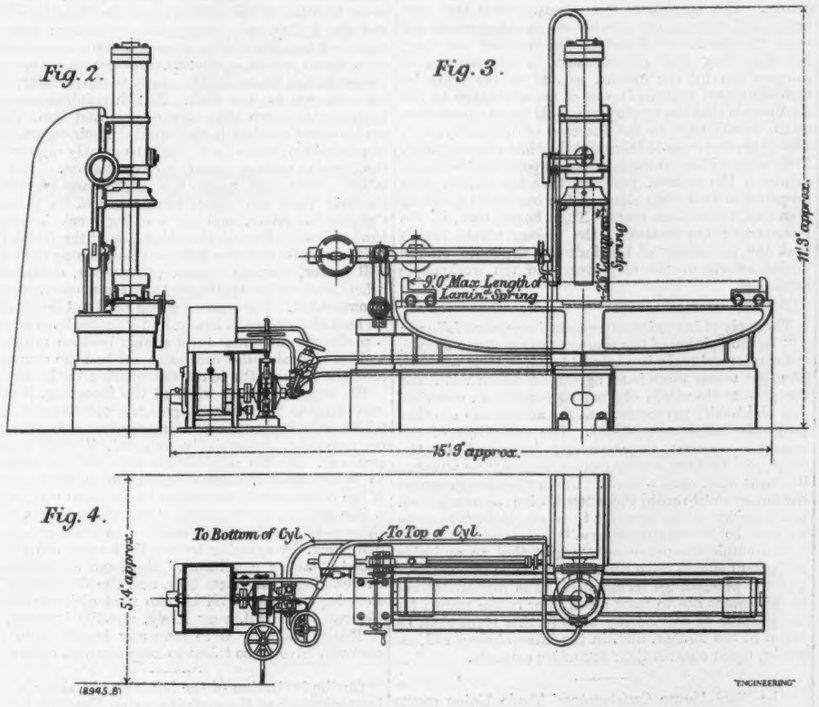
READERS of the monthly Statistical Bulletin of the National Federation of Iron and Steel Manufacturers will have been prepared for much of the evidence that Sir William Larke, the Director of the Federation, gave to the Committee on Industry and Trade. The Federation represents within 3 per cent. of the total steel production of the country and nearly nine-tenths of the pig-iron and wrought-iron production, and Sir William's evidence focusses some striking facts in regard to the industry. It employs a capital of 150,000,000*l.*, and the value of its exports in 1924, though not much more than a third of that of the cotton manufacturers, were the next largest single item. It is connected with peculiar intimacy with the railway service, and with the shipbuilding industry. Its traffic provides 15 to 20 per cent. of the revenue of British railways, and their charges, which are said to be about twice to three times as high as Continental rates for equivalent services, represent 15 to 25 per cent. of the selling price—not the cost—of its products. About 20 per cent. of the home consumption of steel is used in shipbuilding.

Except for the sheet and tinplate trades, the iron and steel industry shares the depression of the shipbuilding and engineering trades. Of its insured workpeople, the proportion unemployed is roughly double as large as the average for all trades; of its blast-furnaces, just over one-third are alight, as against nearly twice as many in 1913; of its steel plants, about an eighth in productive capacity are idle, and in the Midland wrought-iron industry alone 20 works have been shut down, and much of the plant dismantled. The production of steel in 1924 was, indeed, about 10 per cent. more than in 1913, but that of pig-iron was some 30 per cent. less, while, as compared with 1913, the imports of the iron and steel industry in 1924 were some 10 per cent. more, and the exports some 20 per cent. less. This situation is attributed partly to the condition of the industries that consume iron and steel, partly to increased production in the Dominions, and partly to under-consumption throughout the world, arising from lack of credit and the hope of lower prices. Though he estimates that the demand from non-producing countries in 1924 was about 5,000,000 tons less than in 1913, Sir William sees good reason for believing that the potential world demand should be enough to employ the world's full present production capacity; but the present lack of demand has stimulated competition so unhealthily that in Europe prices often have little relation to costs.

France has derived advantage from its depreciated exchange, France, Belgium and Germany from their lower capital charges, and the Continent generally from their lower wages (about three-fifths of what are paid in this country) and longer hours, lower transport charges and protected home

SPRING TESTING MACHINE.

CONSTRUCTED BY MESSRS. W. AND T. AVERY, LIMITED, ENGINEERS, BIRMINGHAM.



markets, which secure to their works employment for a proportion of their output. In addition, Continental makers have the benefit of much lower taxation and rating. In Great Britain, between 8*s.* 6*d.* and 11*s.* 8*d.* per ton of steel is spent on local rates and social services, as against about one-third of those rates in 1913, while on the Continent income-tax is not charged on profits carried to reserve, or spent on development. Nevertheless, prices are only 35 per cent. above those of 1913, against a rise of double that percentage for all commodities. In Sir William's judgment, no further substantial reduction of costs is possible until the general price level in this country of all commodities and services has been reduced, in the same way as by the operation of the sliding scale for wages and other economies, the prices of iron and steel have been reduced.

The mechanism for adjusting differences between employers and employed has worked so effectively that for 30 years no serious stoppage has originated within the industry. It is based on mutual confidence and frankness, and neither side had ever broken an agreement. Sir William deprecated for the industry either State regulation of wages, compulsory arbitration, or legal enforcement or compulsory extension of agreements. While the equipment of most large works in the country is said to be unsurpassed by any in the world, the industry is fully alive to the possibility of further improvement, and both on its own account at works throughout the country, with the co-operation of the Department of Scientific and Industrial Research, and with the help of Universities and scientific institutions, is promoting and actively supporting a vigorous policy of research of all kinds with a view to improving products and reducing costs.

SPRING-TESTING MACHINE FOR WEIGHING AND REPETITION TESTS.

AT the recent British Industries Fair, Messrs. W. and T. Avery, Limited, of Birmingham, showed a 20-ton spring-testing machine for static or dynamic tests on springs of either the spiral or flat laminated types. This is a development of the testing and scragging machines of Messrs. Avery with which we have dealt in the past. We illustrate the new machine in Figs. 1 to 4, on the opposite page, and above. It consists generally of a weighing table on which the spring rests and a hydraulic ram by means of which the load is applied. A steelyard connected to the weighing table permits of the load being regulated by means of a sliding weight. The amount of the load is determined by the position of this weight, and is indicated on a scale attached to the steelyard. The oil for operating the ram is circulated by the Hele-Shaw pump, driven by a small electric motor, which can be seen on the left of the machine. By screwing the horizontal hand wheel to the right or left the oil can be directed either above or below the ram. When it is desired to make a static test the pump is regulated by the hand wheel to give a slow downward movement of the ram, and the spring can be kept at any desired degree of compression by closing the valve shown in an inclined position to the right of the pump. This closes the oil circuit and thus locks the ram in any desired position. For dynamic or repetition tests the hand wheel controlling the pump is disconnected by removing a pin, and direct control is then given by means of the hand lever, which can be seen projecting beyond the hand wheel in plan, Fig. 4. This performs the same function as the hand wheel, but, as it can be operated much more rapidly than the latter, it enables the spring to be repeatedly loaded and released comparatively quickly. The cylinder and ram are designed to give a much quicker return than forward stroke, and a by-pass valve is provided on the pump to allow the surplus oil to escape when the ram is rising.

The weighing portion of the machine is entirely self-contained in a substantial cast-iron frame, which effectually secures the main levers and suspension links from dust and grit. The main levers are machined and fitted with long, continuous, hardened-steel knife-edges. The levers are suspended by means of cast-steel links having hardened-steel bearings. The platform is fitted with cast-iron verges, having hardened-steel bearing blocks, which rest upon the lever knife-edges. Two trolleys are provided, and are used in the case of laminated or flat springs. They run upon planed tracks on the upper surface of the platform. The poise is propelled by means of gear wheels having machine-cut teeth, and a screw operated by a chain from the hand wheel, which can be seen at the base of the steelyard column in Fig. 3. The graduations are clearly engraved by machine and read by divisions of one cwt., a vernier attachment enabling readings to be made to 14 lb. A tare bar and poise are provided for balancing the weight of the springs, the bar being graduated in sub-divisions of 14 lb. up to 10 cwt.

A cast-iron balance weight bolted to the back arm places the steelyard in equilibrium when the travelling poise is at zero. A graduated deflection scale is fitted upon the main column, and this is traversed by a pointer upon the top platen. Deflections of one-tenth of an inch are clearly indicated by this arrangement. A dial on the side of the cylinder column, graduated in inches, gives a rough indication of the movement of the ram to the pump operator.

THE LATE MR. ROBERT HARVEY.

MR. ROBERT HARVEY, for many years the chairman of the Harvey Engineering Company, Limited, of Glasgow, the well-known sugar machinery builders, died at his residence, Oaklands, Sherbrooke, Pollokshields, on Monday, March 9, at the age of 76 years.

He was a native of Glasgow, and was the son of the managing partner in the firm of Messrs. David Cook and Co. Into this business Mr. Harvey entered after completing his education at the Glasgow High School and the Andersonian College, and he eventually became works manager. He also obtained engineering experience with Messrs. Randolph, Elder and Co., which eventually became the Fairfield Shipbuilding and Engineering Company, Limited, and was also for some years on the staff of an English company making sugar machinery. On the termination of the business of Messrs. David Cook and Co., his father purchased the best of the plant and started new works at Kinning Park. In the business of the new concern Mr. Robert Harvey and his brother William joined, and in 1880, when the father retired, Mr. Robert Harvey became the senior partner. Six years later, with the late Sir William M'Onie, the firm of M'Onie, Harvey and Co. was founded, in which Mr. Harvey was managing director. This organisation was later renamed the Harvey Engineering Company, and so remains to-day.

He was the inventor of the Harvey evaporator for the removal of water from sugar cane juice, and visited the West Indies in 1905 at the request of the Government to report on the erection of central sugar factories, and earned appreciation for the services he thus rendered. Owing to a breakdown in health he retired some years ago from the business, which since then has been managed by Mr. James Harvey.

In addition to his work as a manufacturer of sugar machinery, which entailed frequent visits to the sugar-growing countries, Mr. Harvey had many interests. He contributed freely to the knowledge of the history of engineering in Glasgow, as well as of sugar machinery and the cane sugar industries, and was the author of three interesting volumes on these subjects. In his quest for information on the history of engineering Mr. Harvey became the possessor of many original drawings made by the pioneers in shipbuilding, marine engineering, and in the design of sugar machinery. These, with a volume on the history of his firm, Mr. Harvey presented in 1916 to the Corporation of Glasgow for preservation in the Kelvingrove Galleries, since when they have been available to all students of the subjects. Mr. Harvey was a water-colour artist of considerable ability, and devoted much of his spare time to this pursuit.

THE INSTITUTE OF STREET LIGHTING ENGINEERS.—A week or so ago a visit was paid by the Institution of Street Lighting Engineers to the Osram-G.E.C. Lamp Works at Hammersmith, London, rendered possible by the courtesy of the General Electric Company, Limited, of Magnet House, Kingsway, London, W.C. 2. The processes involved in the manufacture of electric lamps and radio valves of various sizes, which we have already given some account of in our columns, were carefully and clearly expounded and illustrated to a large representative body of gas, electric, and other engineers who participated in the tour of inspection of the works. Much attention was in particular given to the preparation of tungsten wire from the ore and the chemical and physical treatment of the substance, such as purification, sintering, and drawing, was exhibited in up-to-date shop methods. At the conclusion of the visit, the Secretary of the Institution, Captain W. J. Liberty, acknowledged the attention of the staff of the works.

THE JUNIOR INSTITUTION OF ENGINEERS.—At a recent meeting an interesting and able discourse was given before the Junior Institution of Engineers by Mr. Loughnan Pendred, the editor of *The Engineer*, who chose for the subject of his Honorary Member's lecture "Milestones in the Development of the Prime-Mover Locomotive." A continuous group of lantern slides were used to illustrate the distinctive types of locomotives constructed, including the earliest and the latest models. In recognising that the days of the reciprocating steam engine were numbered, the lecturer sounded a warning note regarding the complete dependence of the nation on a few central power stations, which would result if electrification of our railways were completely adopted. Such a state of affairs would render it possible for the trade of the country to be completely paralysed in the event of trade unionists ceasing to work these sources of power. Dr. Alexander Russell, the President of the Institution, occupied the chair, and moved a vote of thanks to Mr. Pendred at the end of the proceedings.

LABOUR NOTES.

ON Thursday last week the council of the Mining Association and the executive of the Miners' Federation of Great Britain agreed to appoint a joint committee to investigate the whole economic position of the industry. The first meeting of the committee is to be held on Wednesday next. Three points which the coal-owners suggested required investigation were :—

(1) The export trade, with the cost of production in this country and by our trade competitors in other countries.

(2) The inland trade and its possibilities both as to industrial and domestic coal.

(3) The cost of production, and the methods of production with regard to output at the various collieries.

The miners' representatives made the following suggestions :—

That the accountants should be allowed access to all necessary books, accounts and documents, and have the right to make an unrestricted test audit.

That the workmen's accountants should have the right to call in representatives of the workmen to advise upon questions which involve capital expenditure.

Discussion of the desirability of including the earnings of coking and bye-product plants, smokeless fuel plants, electrical power plants, washeries, &c., patent fuel selling agencies, merchanting depots, and all activities which are directly connected with the coal industry.

Discussion and examination of the present organisation of production, with a view to better results being obtained.

With respect to the administration at the collieries, discussion on the number of certain classes of officials as compared with pre-war, the amount of directors' fees, and the buying of colliery stores and timber.

That before any colliery was closed down owing to alleged financial difficulties an inquiry into the circumstances should first be held.

All the evidence and findings are to be reported by the executive to a delegate conference for its consideration and decision.

There was again failure to agree on the wages question at a conference in London last week between representatives of the engineering employers and representatives of the engineering trade unions. At a meeting on February 11, Sir Allan Smith, on behalf of the employers, made the following offer :—

"The employers being of opinion that the present state and prospects of the industry do not warrant any increase in the load of production costs, but being willing to meet, as far as possible, the claim of the unions for an advance, and being anxious to arrive at an amicable settlement and so foster the industry, feel that they are not warranted in deciding the amount of advance to be given unless and until the unions have demonstrated the extent to which they are prepared to modify existing working conditions and thus avoid damaging the prospects of the industry at this extremely critical stage. The employers repeat the offer already made to proceed with the negotiations on the foregoing basis."

The representatives of the unions declared that they had no mandate to discuss existing working conditions, and intimated that unless the employers were prepared to make an offer of a definite amount, they had no alternative but to report the present position to their respective executives. At the opening of last week's conference they intimated that, in their opinion, there was no warrant for any interference with any of the present agreements. They therefore requested the employers to state their decision with respect to the application for a wages advance.

To that, Sir Allan Smith, on behalf of the employers, made the following reply :—

"The employers have considered the reply of the unions to the proposal put before them by the employers at the conference on February 11, 1925. When considering the reply, the employers have had regard to the following :—

(*a*) The lower rates of wages and longer working week in competitive countries.

(*b*) The facilities, direct and indirect, which are given to producers in the various competing countries by their Governments.

(*c*) The ability of Continental countries to undersell this country owing to the continued depreciation of their currencies.

(*d*) The abnormal credits given by foreign competitors in their efforts to capture the world's markets.

(*e*) The returns of the relation of manufacturing costs to selling values in 1924 with a greater output show a much smaller credit balance than in 1923.

(*f*) Engineering imports are increasing as to value per ton, and exports are decreasing as to value per ton.

(*g*) The result is that there is great unemployment in this country on engineering products."

Proceeding, Sir Allan said that, in view of these considerations and the present conditions and prospects of the industry, the employers, having regard to their obligations to the industry and also to the national interests, had arrived at the conclusion that they were unable to accept the suggestion submitted by the unions. The employers were disappointed that the unions had come to the conclusion that they would not share the burden of fostering the industry and they felt that they were not entitled, in the absence of co-operation by the unions, to add to the costs by increasing the wages. It was of no advantage to the workpeople that the employers should make concessions which would lead to the increase of unemployment. The employers repeated the offer they had already made. They were willing to meet, as far as possible, the application of the unions, provided that the unions were prepared to bear their share of the burden of avoiding increased production costs. They hoped that, in the interests of the industry, the unions would realise that the prosperity of the industry depended on the united efforts of the employers and the workpeople employed.

The reply of the union representatives was as follows :

"In the opinion of the representatives of the unions, the employers' reply is a refusal to concede an advance in wages unless there is an agreement which will lower the present standards of working conditions, overtime and night-shift payments, and the acceptance of other proposals indefinitely stated. The executives of the unions concerned have already intimated to the employers that the unions cannot negotiate an advance in wages upon such a basis. Under the circumstances the unions must regard these negotiations as terminated, and consider themselves free to take such further steps as may be deemed necessary."

The employers expressed "regret that an amicable settlement should have been thus rendered impossible," and the proceedings terminated. The representatives of the unions are to meet again later in the month for the purpose of considering what further steps shall be taken in the matter, and, in the interval they will, no doubt, again consult their executive councils.

The Steel House Constructors' Trade Union seems to be assured of the opposition of the National Federation of Building Trade Operatives, whose secretary, Mr. Richard Coppock, described it to a Press representative the other day as "a political organisation." "There is no need," he said, "for such an organisation in this country, as there is a Steel Constructors' Union in existence which has been established for 16 years. To talk glibly of an organisation of steel house erectors presupposes that steel houses have been built for centuries. One knows that such construction calls for a tremendous amount of timber and ordinary house-building materials, and the steel outer coating is only a fractional part of the erection of the house. Therefore, no matter what Mr. Seddon may do, the facts are that building trade operatives are bound to be used in the erection of these wood and steel houses, and difficulties are bound to arise," Mr. Coppock declared, "on the formation of a 'black-leg' union of this character." The erection of steel houses is, of course, very different from the work done by members of the Steel Constructor's Union, so that, in reality, there is no point in these observations of Mr. Coppock. The "trade" is a new one, and workers who take it up are as much entitled to organise themselves as any of the groups belonging to Mr. Coppock's federation.

The Ministry of Labour states that on March 2, 1925, the number of unemployed persons on the registers of Employment Exchanges in Great Britain was 1,237,700, viz.: 951,000 men, 34,500 boys, 220,700 women and 31,500 girls. On February 23, 1925, the number was 1,236,065, or 945,103 men, 34,510 boys, 223,900 women, and 32,552 girls; while on March 3, 1924, it was, 1,134,742, made up of 834,871 men, 35,359 boys, 229,475 women, and 35,037 girls.

Messrs. Furness, Withy's order from German builders of five new motorships for the Prince Line has served, at any rate, the useful purpose of focussing public attention on the heavy handicap under which the British shipbuilding industry is struggling to carry on. The new units are to be twin-screw ships of 10,000 tons deadweight and fitted with Burmeister and Wain Diesel engines developing sufficient power to give them a sea speed of 14½ knots. The contract price is understood to be about 153,000*l.* per ship, and the nearest British tender was 213,000*l.* per ship. The next—next British, that is—price was 220,000*l.* per ship, and there was a still higher quotation, including full charges, of 254,000*l.* On behalf of Messrs. Furness, Withy and Co., Sir Frederick Lewis offered to give British builders the contracts at 10,000*l.* more than the German price, but none could see their way to agree to the proposal.

Obviously, to have contracted to build the ships at the German price plus 10,000*l.* would have involved the British firm which undertook the work in heavy loss, for in none of the tenders was anything reckoned for profit, and in two charges were radically cut. There is a doubt whether on the prices quoted the Deutsche Werfte and the A.E.G. will jointly do any better; but the mere fact that the combination is content to take a risk at a figure which is 60,000*l.* less per ship than the lowest British tender points clearly to the certainty that our costs are far too high. British shipbuilders have greater experience than any others, and their plants are the most efficient in the world. Their organisation of production, while good, could be greatly improved if the trade unions cared to co-operate. But its labour costs are much too high, largely because its wage rates are higher than those of its principal Continental rivals, and its working week is shorter than it is anywhere on the other side of the North Sea. Its fuel and its steel are dear, and threatening to become still dearer, because miners, railwaymen, dockers and other workers in sheltered trades are extravagantly remunerated. For reasons which need not be specified its load of taxation is heavy, and its rates have reached a positively ridiculous level simply because municipal and other local authorities have not had the courage to look the facts of the industrial position in the face.

We suggest that, in view of the foregoing, it is not surprising to find contracts going abroad to countries in which industry's corresponding burdens are, artificially or naturally, appreciably reduced, if not actually removed. British shipbuilders have striven valiantly to bring down the costs which are in their control. If the others are to be treated in the same way, and to a like extent, trade unions, local authorities and the Government will have to assist—the trade unions, for one thing, by agreeing to re-adjust what are broadly called "labour conditions," the local authorities by overhauling their wages bills, and the Government by reducing taxation. Within the next eighteen months German costs will, very likely, steadily increase, but if British industry is to reap any benefit from that, care will have to be taken to keep our own costs down.

On the invitation of the Minister of Labour a meeting took place at Montagu House, on Tuesday, between a representative of Messrs. J. and G. Weir, Limited, and representatives of the National Federation of Building Trades Operatives, with a view to ascertaining the possibility of reconciling the views of the firm and the Federation as to the wages and conditions to be observed in the construction of steel houses of the Weir type. No agreement was reached. The officials of the Ministry of Labour who were present subsequently reported the position to the Minister, and it was decided to hold a Court of Inquiry under the Industrial Courts Act.

Yesterday and on Wednesday, conferences took place in London between the executive of the Miners Federation and the executives of several other important trade unions for the purpose of discussing the miners' proposal that the various interests should support each other on the wages questions which are under discussion. The representatives of the National Union of Railwaymen and the Transport Workers' Federation, were met on Wednesday. At the close of the discussions with the railwaymen, it was officially stated that the proceedings were largely informal and that it was probable a further meeting would be held. After the conference with the transport workers, the following official communication was issued :—"After Mr. Herbert Smith and Mr. A. J. Cook had explained the objects of the meeting, Mr. Ben Tillett and Mr. Robert Williams presented the case for the Transport Workers Federation. A frank discussion took place on the whole position, which will be considered by both organisations and subsequent meetings will be arranged. Yesterday the matter was discussed by the miners with representatives of the Amalgamated Engineering Union, and also with representatives of other organisations of engineering and shipbuilding operatives. Arrangements have been made to meet the Associated Society of Locomotive Engineers and Firemen. So far, the miners' proposals have not been received with enthusiasm by the general body of workers.

According to the Amalgamated Engineering Union's *Monthly Journal*, the home branch membership of the organisation increased from 212,066 to 213,483 in February, and the Colonial branch membership decreased from 25,796 to 25,727. After the usual adjustments, the unemployed figure works out at 7·15 per cent. It is officially announced that from May 2, the payment of donation benefit will be resumed, but only at the rate of 5*s.* per week. It will be payable for not more than 15 weeks in any twelve months, and only to members who are not in arrears with their contributions.

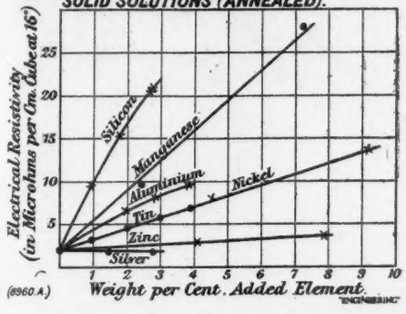
THE ELECTRICAL RESISTIVITY OF COPPER.

*Note on the Effects of Certain Elements on the Electrical Resistivity of Copper.**

By A. L. NORBURY, M.Sc.

Present Data.—Certain copper *a* solid solution alloys which had been made homogeneous by annealing were cold-rolled and drawn (with intermediate annealings), into 0·1-in. diameter wires. The electrical resistivities of the wires in the "as received" (more or less cold-drawn) condition are given in Table I, in which table are also shown the resistivities of the same wires after annealing at a red heat by passing them through a Bunsen flame. Tests were made, which indicated that the superficial oxidation caused by this annealing was not sufficient to have affected the electrical resistivities.† The latter were measured at 16 deg. C. over two or three 1·0-m. lengths, using the drop of potential method and a Tinsley potentiometer. The results obtained for the annealed wires are plotted in Fig. 1.

Fig. 1. ELECTRICAL RESISTIVITIES OF COPPER *a* SOLID SOLUTIONS (ANNEALED).



Atomic Effects of Solutes on Resistivity of Copper.—From the curves in Fig. 1 it is calculated that the "increase in the specific resistivity of copper due to the presence in solid solution of 1·0 atomic per cent. added element" is for each element as follows‡: Aluminium, 1·1; silicon, 3·8; manganese, 3·1; nickel, 1·2; zinc, 0·27; silver, 0·14; tin, 2·4.

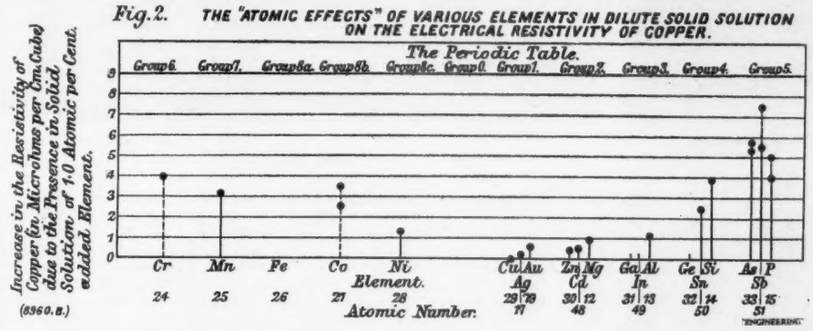
In a previous paper§ all the obtainable published data on the subject were collected and analysed, and gave the following for the "atomic effects": Magnesium, 0·8; aluminium, 0·8; silicon, 3·0; phosphorus, 4·0–5·0; chromium, 4·0; manganese 2·9–3·0; iron, 2·0‖; cobalt, 2·5–3·5; nickel, 1·1, 1·2; zinc, 0·26–0·31, 0·29–0·30; arsenic, 5·3, 5·6, 5·5; silver, 0·22, 0·13–0·22; tin, 2·6, 2·6; antimony, 4·0–5·0, 5·5–7·5; gold, 0·5–0·65, 0·60–0·64. It will be seen that the values obtained in the present research for aluminium and silicon are somewhat higher than those previously published. For all the other elements, however, the present values are very much the same as the previous ones. In Fig. 2 the "atomic effects" of the various solute elements are plotted as they were in the original paper, but with the present results included. The "atomic effect," cadmium 0·28, calculated from the results obtained by Smith,* is also included in Fig. 2.

It will be seen from Fig. 2 that the present values lend support to the conclusion previously arrived at, that "the relative atomic effects are small when there is little 'affinity' between atoms of solute and solvent, and large according as the 'affinity' between the two is greater."

TABLE I.—*Electrical Resistivities of Copper a Solid Solutions.*

Composition. Added Element.	Weight per cent.	Electrical Resistivity. Microhms per cm. Cube at 16 deg. C. As Received.	Annealed at 700 deg. C.
Copper	pure	—	1·70
Aluminium	1·92	6·92	6·64
,, ...	2·88	8·77	8·05
,, ...	3·82	10·45	9·27
Silicon	0·93	9·24	9·50
,, ...	1·71	15·58	15·24
,, ...	2·67	—	20·54
,, ...	2·71	21·82	20·80
Manganese	2·40	9·83	9·85
,, ...	7·20	28·80	28·88
Nickel	4·52	7·89	7·91
,, ...	9·20	13·61	13·58
Zinc	4·06	2·82	2·71
,, ...	7·86	3·70	3·58
,, ...	11·66	4·42	4·15
,, ...	15·58	5·19	4·74
Silver	1·44	1·93	1·87
,, ...	2·75	2·01	1·93
Tin	1·00	3·15	3·13
,, ...	2·03	4·50	4·40
,, ...	2·96	5·83	5·65
,, ...	3·88	—	7·00

Fig. 2. THE "ATOMIC EFFECTS" OF VARIOUS ELEMENTS IN DILUTE SOLID SOLUTION ON THE ELECTRICAL RESISTIVITY OF COPPER.


Increase in the Resistivity of Copper (in Microhms per Cm. Cube) due to the Presence in Solid Solution of 1·0 Atomic per Cent. added Element.
The Periodic Table.
Group 6 Group 7 Group 8a Group 8b Group 8c Group 0 Group 1 Group 2 Group 3 Group 4 Group 5
Cr Mn Fe Co Ni Cu Ag Au Zn Cd Mg Ga In Al Ge Sn Si As Sb P
Element.
24 25 26 27 28 29 47 79 30 48 12 31 49 13 32 50 14 33 51 15
Atomic Number.
(8960.B.)

RECENT DEVELOPMENTS IN CORROSION-RESISTING STEELS.†

By DR. W. H. HATFIELD.

THE paper opened with a discussion of corrosion as affecting ordinary ferrous materials, and expressed the view that generally the results as regards structural and engineering steels were not perhaps so serious as was frequently stated. Nevertheless, whilst important structures were retained unimpaired by constant attention, and more or less complex mechanical devices, as typified by the railway engine and motor car, operated for a reasonable life without overall serious dilapidation through corrosion effects, there were items or parts essential to the operation of the latter where atmospheric and temperature effects were serious, and necessitated replacements; as regards the former, local corrosion in inaccessible places was a constant danger. Corrosion, therefore, as regards ferrous materials, was indeed an important subject for the engineer, and it was useful to review the results of research and experience over the last few decades.

The results of comparative corrosion tests performed on structural and ordinary engineering steels in a range of acids and corroding media showed that the presence of oxide of iron, or high sulphur and phosphorus content, facilitated attack upon the materials. Dead mild steels with a considerable manganese content were much less resistant, particularly to marine conditions, than the wrought irons. The indifferent behaviour of the mild steels was emphasised when the steel was produced by processes involving over-oxidation of the liquid steel during the process of manufacture.

In connection with the improvement in the resistance to corroding influences obtained by the addition of special elements to steel, modern research had demonstrated that only by the addition of substantial percentages of chromium or nickel, or chromium and nickel, could effective corrosion-resisting steels, suitable for engineering purposes, be produced. Attempts to influence the resistance of steel in this respect by the addition of small percentages of various elements had proved ineffective, and this aspect of the matter was typified by the unsuccessful attempts to improve steel by small additions of copper. Nickel added in substantial amounts, namely, 25 to 30 per cent., had a profound effect in increasing the resistance of steel to a number of corroding media, but the first real economic advance had resulted from a study of the steels included in the iron-carbon-chromium system. It was found that, as regards this series of chromium steels, there was, for many purposes, an optimum percentage of chromium of 13 to 14 per cent., which, when present with a carbon content ranging from 0·35 per cent. down to under 0·10 per cent., produced an extremely valuable series of steels, which were resistant to most atmospheric and food influences. Such steels might be obtained suitable for purposes requiring the characteristics of hardened steel, the machining and mechanical properties for engineering purposes, or a substantial ductility as required for many minor purposes. The resistance of such steels, however, was naturally only satisfactory as regards a limited range of corroding media. If, along with the still higher chromium content, a substantial proportion of nickel was added, complete resistance to a much wider range of corroding media was obtained, as illustrated by the following table. Although the 14 per cent. chromium steels resist many reagents, there are a number which they do not resist. The following table gives examples of instances where the higher chromium-nickel steel is successful, and the 14 per cent. chromium steel is not resistant.

Reagent.	14 Per Cent. Chromium Steel. (Machinable Condition.)	18 Per Cent. Chromium, 8 Per Cent. Nickel Steel.
Phosphoric acid—		
5 per cent. ..	2 days, 15 deg. C.	Attacked.	Unaffected.
25 per cent. ..		
50 per cent. ..		
75 per cent. ..		
Acetic acid—		
6·6 per cent. ..	7 days, 15 deg. C.	Attacked.	Unaffected.
16·5 per cent. ..		
33·0 per cent. ..		
Formic acid—		
5·0 per cent. ..	7 days, 15 deg. C.	Attacked.	Unaffected.
50·0 per cent. ..		
Conc. ..		
Tartaric acid—		
5 per cent. ..	28 days, 15 deg. C.	Attacked.	Unaffected.
25 per cent. ..		
Citric acid—		
4 per cent. ..	24 hours, 15 deg. C.	Attacked.	Unaffected.
6 per cent. ..		
10 per cent. ..		
B.P. lactic acid	7 days, 15 deg. C.	Attacked.	Unaffected.
Calcium chloride—		
10 per cent. ..	14 days, 15 deg. C.	Attacked.	Unaffected.
20 per cent. ..		
30 per cent. ..		
50 per cent. ..		
70 per cent. ..		
Ammonium sulphate, saturated	28 days, 15 deg. C.	Attacked.	Unaffected.
Sodium sulphate, saturated	7 days, 15 deg. C.	Attacked.	Unaffected.
Sea water, partial immersion ..		Slightly attacked.	Unaffected.
2 per cent. iodine solution		Attacked.	Unaffected.

The modification in the composition of the steels which led to improved corrosion resistance also conferred upon them a resistance to oxidation, coupled with increased strength, at high temperatures. Such factors as concentration, temperature, and the general physical conditions involved in the environment of the units under consideration were of very great importance.

COURSES OF INSTRUCTION FOR TEACHERS IN TECHNICAL SCHOOLS.—Arrangements have been made by the Board of Education to give short courses in engineering science, electrical engineering and mining engineering. The classes in the two first-mentioned subjects will be held at the University of Birmingham from Monday, July 13, to Saturday, July 18, and thereafter at Oriel College, Oxford, until Wednesday, July 29. The mining engineering course will be given at Birmingham from Wednesday, July 8, to Saturday, July 18. During these periods demonstrations will be made of the methods of performing test work and lectures will be given by authorities in science and engineering. The number of students that can be dealt with is limited, and applications must be made on Form 106e U, as soon as possible, to the Board of Education, who will make a selection from them. Railway fares will be met by the Board, who will also make a grant towards maintenance.

* Paper read before the Institute of Metals, London, on Thursday, March 12, 1925.

† In the case of the zinc-copper alloys, superficial dezincification had apparently occurred during drawing, &c., and, in consequence, their resistivities shown in Table I are probably too low.

‡ For 1 per cent. by weight of each added element the following increases in the specific resistivity of copper are calculated from Fig. 1: aluminium, 2·6; silicon, 8·6; manganese, 3·6; nickel, 1·3; zinc, 0·26; silver, 0·09; tin, 1·3.

§ *Trans. Faraday Soc.*, 1921, 17, 251.

‖ This result is valueless, since Hanson and Ford (*J. Inst. Metals*, 1924, 32) have shown that copper can normally hold only 0·2 per cent. of iron in solid solution.

* W. C. Smith, *Chem. and Met. Eng.*, 1921, 25, 1178.

† Abstract of a paper read before the N.W. Branch of the Institution of Mechanical Engineers at Manchester, on March 5th, 1925.

21-FT. LARNER-JOHNSON PENSTOCK VALVES; NIAGARA FALLS POWER COMPANY.

Fig. 1

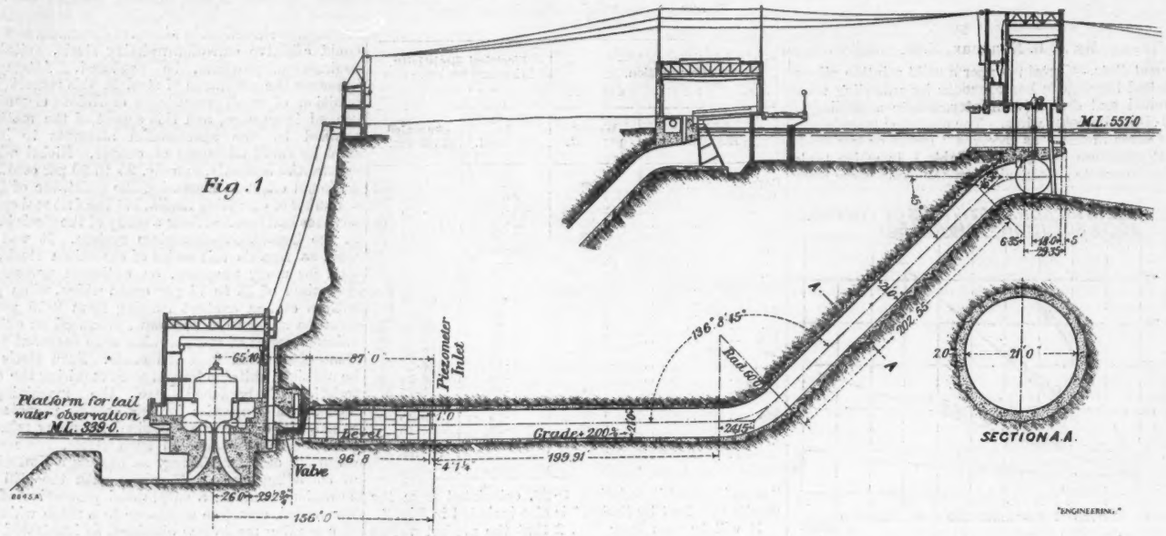


Fig. 2.

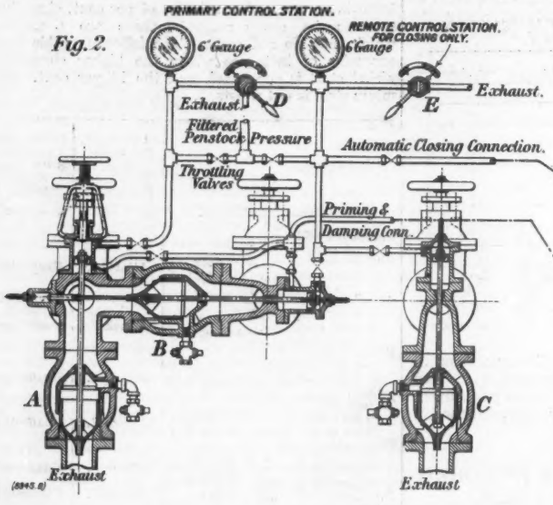
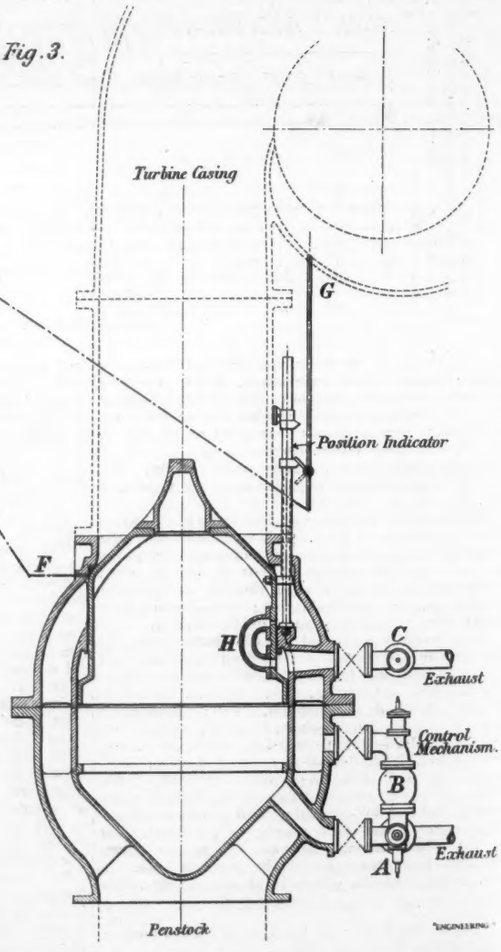


Fig. 3.



21-FT. LARNER-JOHNSON PENSTOCK VALVES.

THE largest hydraulic turbines in existence at present are three 70,000 h.p. units recently placed in service at the extension to the plant of the Niagara Falls Power Company. These turbines are supplied through penstocks no less than 21 ft. in diameter, as shown in Fig. 1 above, the supply being controlled by 21-ft. Larner-Johnson valves, the location of which at the power station is indicated by dotted lines which show an enlargement of the pipe line just where this runs into the station structure. The entrance to the turbine casing is 14 ft. in diameter. The static head under which the valves work is about 200 ft. and the controls are fitted immediately over the valve bodies on the power-house floor. The type of control fitted is illustrated in Figs. 2 and 3, while Figs. 4 and 5 opposite show, in the makers' shop (Messrs. Wm. Cramp and Sons Ship and Engine Building Company, Philadelphia, Pa.), part of the valve casing and body, and the moving piston, respectively.

The valves have an overall length of 30 ft. and a maximum diameter of 25 ft. 9 in. One complete valve weighs 274·5 tons, the plunger or piston alone weighing no less than 48·2 tons. Each valve required as many as nine railroad cars for shipment, the main body having to be made in three sections to come within the loading gauge. The ruling thickness of the cast steel body is 2⅛ in. The manner in which these valves work was fully described in an article in ENGINEERING, Vol. cxiv, page 35, when we dealt with the Larner-Johnson valves installed for the Queenston-Chippawa Development station. In that case the valves were for 14 ft. penstocks.

The three control valves fitted to the large Niagara valves are 10-in., each consisting of a plunger with an internal stem, which is allowed a slight movement and acts as a pilot valve seating on a port in the plunger nose. The plungers are moved by the water pressure as controlled by the pilot valves. The details of control may be explained by means of Figs. 2 and 3, in which the three auxiliary valves A, B and C are actually the same fittings. Each of these valves is fitted with a gate-valve to isolate the control-valve for inspection, &c. The chain-dotted lines in Figs. 2 and 3, represent diagrammatically leads from different points of the penstock and scroll, by means of which the requisite hydraulic pressure for operating the controls is transmitted to the valves. Each control valve is fitted with a plunger on a piston rod, on which is provided at the other end a piston working in a cylinder. These pistons are moved in their cylinders if any difference in the pressure occurs on either side of them. The plungers of the valves are consequently operated, and in turn the main valve is worked. The valves A, B and C are normally closed.

Supposing the main valve to be closed as shown in Fig. 3, to open it the handle of the cock D, Fig. 2, is swung to the left, connecting the upper side of the piston of valve A with the exhaust. The pipe connecting with F in the main valve casing, Fig. 3, maintains penstock pressure on the underside of the piston of A. The plunger of A is therefore moved off its seat, and this connects the interior of the main plunger, Fig. 3, with the exhaust. The main plunger is then free to move off its seat, this movement being accomplished by water under penstock pressure entering by the port H, and flowing into the annular space between the plunger proper and its casing. After a small movement, the port H is closed and the movement is continued at a reduced rate as a result of leakage around the plunger. The actual speed depends upon the amount by which the control valve A is opened. This can be regulated by a screw-adjustable stop in the

21-FT. LARNER-JOHNSON PENSTOCK VALVES; NIAGARA FALLS POWER COMPANY.

FIG. 4.

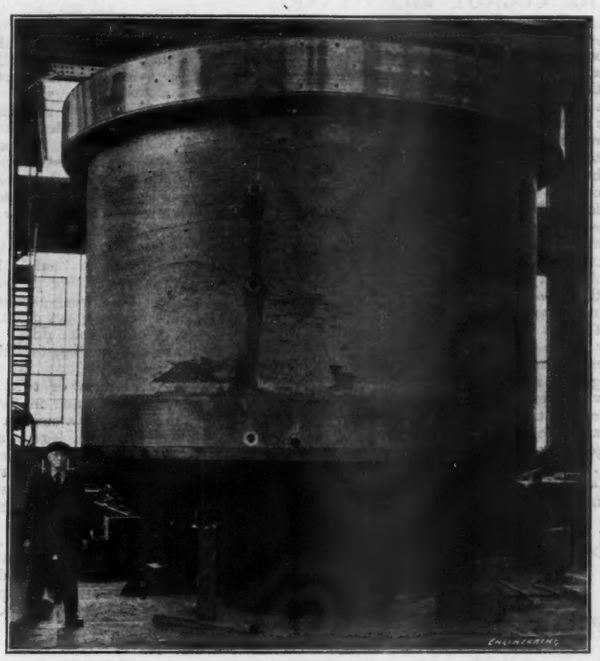


FIG. 5.

cylinder cover which limits the movement of the piston by which A is worked. The port H allows a considerable amount of pressure to be exerted on the main plunger at first. in order to unseat it.

As soon as the main valve is unseated, the flow of water through the small opening at high velocity reduces the pressure at F and in the pipe connecting with the underside of the piston of A. This fall of pressure checks the movement of A, and throttles the discharge from the interior of the main valve. The latter, therefore, remains practically stationary, while the turbine casing is primed, after which pressure again builds up, and the piston of A is moved to the end of its adjusted travel. The main valve can then continue its opening movement.

The main valve is closed by the handle of either of the valves D or E being swung over to the right. This causes the pressure above the pistons of the valves B and C to drop, and both these valves are opened. From Fig. 3 it will be observed that the effect of opening C is to exhaust the water from the annular space round the main plunger, while through B water at penstock pressure is admitted into the interior of the main plunger. This valve is thus moved towards its seat. When, however, the seat is approached the water passage is reduced; hence the velocity of the flow gradually increases, and the pressure at F is reduced. The piston of B (Fig. 2) thereupon moves to the left until it covers the port connecting with F, when its movement ceases. This movement, of course, affects in a corresponding degree the supply of the water to the inside of the main plunger, the latter therefore being only allowed to move very slowly for the last part of its travel on to its seat, thus avoiding all risk of water hammer. The degree of damping can be regulated by the adjustment of the piston of B on its piston rod, screw adjustment being provided for the purpose.

In the event of an emergency, such as a break in the wheel casing, the main valve is automatically closed. It will be noticed in Fig. 3 that a pipe connection G is inserted in the spiral casing where, in the event of such a failure, the drop in pressure would be greatest. By means of this connection, any sudden pressure drop such as would occur in an emergency, is transmitted to the cylinders of the control valves B and C causing these to open whereupon the main plunger closes, the automatic damping coming into play as before. Two control stations D and E are provided, the former being at the turbine and the latter at any convenient distant point. The distant control valve E only enables the valve to be closed. The emergency connection to G is fitted with a cock, which is operated by the movement of a rod attached to the main plunger. This cock is inserted in order that pressure may be maintained in the system when the main plunger is closed.

In the 21-ft. Niagara valves we have been describing, the main plunger shown in Fig. 5, and in position inside one half of the valve casing in Fig. 4, travels a distance of 6 ft. 4½ in. from the fully open to the closed position. This movement results in a displacement of no less than 12,900 gallons of water from the interior of the valve. When the wheel casing is empty and the valve is closed, there is a force of 565,000 lb. available to unseat the valve. After priming, this force increases to 2,820,000 lb. In closing, a force of 565,000 lb. operates throughout the stroke or until the pressure in the casing beyond the valve falls below normal. When the plunger is seated, or when the valve is being closed in an emergency, the maximum available closing force is 2,820,000 lb. These great forces are not developed in normal working. The plunger, when moving, is in a state of balance and the force moving it is only equal to the opposing force, plus the friction of the guides. Normally the friction is low. If it should increase, the moving force increases in exact relation to the force required. The valves are set to open or close in approximately four minutes, regardless of the flow.

A recent test demonstrated the positive and reliable character of this system of closing the valve in flowing water. The unit was fully loaded, there being a flow through the valve of approximately 3,700 cub. ft. per second. This corresponds to a velocity of 24 ft. per second at the valve outlet. Under these conditions the control handle was operated and the valve plunger moved towards its closed position. With the valve half closed the velocity of water had increased to 48 ft. per second, with very little drop in the power output of the unit. As the plunger progressed the power output decreased until when three-quarters closed the wheel casing pressure was reduced to nearly zero. The plunger at this point was still 19 in. from the seat. Further progress of the plunger cut off the flow of water and stopped the machine. The valve plunger seated without shock or sound of any description. The rate of closing was uniform throughout the stroke, except for a slight retardation just before the plunger seated.

It is believed that this test constitutes a record in shutting off such a large volume of water by means of a penstock valve, in such a short space of time. The total time of closing during this test was four minutes, but the flow of water was cut off by the last 20 per cent. of the stroke, hence the entire flow of 3,700 cub. ft. per second was cut off in less than 1 minute. These valves, as stated above, were designed and built by the Wm. Cramp and Sons Ship and Engine Building Company, of Philadelphia, Pa., this company having the American manufacturing rights for the Larner-Johnson valves for water-power plants. The sole manufacturing rights outside U.S.A. and Canada, for all applications of valves of this type, are in the hands of Messrs. J. Blakeborough and Sons, Limited, Brighouse, Yorkshire.

We may conclude by stating that Messrs. J. Blakeborough and Sons have recently received, among others, orders for three Larner-Johnson valves for the Arapuni Power Supply scheme in New Zealand and two for the Lake Coleridge (New Zealand) Power Scheme. The valves for the Arapuni Scheme are 12 ft. in diameter at the inlet and 20 ft. 3 in. long overall, each weighing about 65 tons. The normal closing time will be 2 minutes, but it will be possible to vary this between 1½ and 3 minutes. The control will embody two automatic features for emergencies. One of these is intended to ensure the closing of the valve in the event of a turbine racing, and the other in the event of failure of the casing and abnormal velocity past the valve. The valves will be controlled from the main-switchboard, from the generator-room floor or by hand or motor at the valve itself, electric indicators in the generator-room and on the switchboard showing the position of the plungers.

MARCONI'S INTERNATIONAL REGISTER.—Next to the actual need existing for any product, the most necessary condition for the establishment and development of trade is that sufficient facilities for economical and convenient communication between buyer and seller should be provided. An admirable aid to this end is available in the third annual edition of Marconi's International Register of Telegraphic and Trade Addresses, published at a price of 52s. 6d. net by the Marconi International Code Company, Limited, of Marconi House, Strand, London, W.C.2. This is an exhaustive work containing, within some 2,500 pages, full particulars of over 73,000 of the leading business houses in the world. Utility to foreign as well as British firms is ensured since classified trades are indexed in the French, German, Spanish, Italian, Portuguese, and Dutch languages. The book is arranged broadly in three sections, the first of which consists of an alphabetical list of important business organisations, the second the classified trades section mentioned, including over 300,000 names under 3,000 trade headings, and the third a list of cable addresses. The latter enables the recipient of a telegraphic message, signed in code, immediately to identify the sender. Further reference to the first portion of the Register provides complete information regarding the codes used by the sender. In addition to the foregoing an "Inreg" five-letter self-contained standard code is included, together with ciphers for phrases and groups of phrases not usually found in codes. An interesting travel section completes a work which should certainly find a place in any office concerned with international trade.

LETTERS TO THE EDITOR.

THE CUGNOT BICENTENARY.

TO THE EDITOR OF ENGINEERING.

SIR,—Adverting to the interesting monograph on the above in your issue of February 27 (page 264 *ante*), it is perhaps of further interest to recall that Cugnot's invention was prompted with the idea of superseding horses for dragging cannon to the battle-field.

The scheme was warmly approved and supported by the French military authorities of that day, but as the inventor's first *voiture à feu* had crashed through a wall, and the second one—a mechanical improvement on its predecessor—had the misfortune to capsize when negotiating a corner during a trial run through the streets of Paris, further experiments were considered too dangerous, and Cugnot's invention being consigned to the Arsenal, no attempts were made to ascertain its possible utility.

Without bearing any relation to the French invention, minds were busy elsewhere on the same subject, and it is not without interest to trace the progressive stages of the development of steam power for haulage purposes, from Cugnot's pioneer and abortive attempt, through the inventions of Murdock and Trevithick in Cornwall, Blenkinsop and Murray at Leeds, and so on to the painstaking colliery-wrights and enginemen of Durham, from whom, after many experiments, emerged George Stephenson with his Locomotion No. 1, the pioneer railroad locomotive of the Stockton and Darlington Railway, the centenary of which will be celebrated this year.

Yours faithfully,
W. P. MEIKLE.

The Croft, Formby, Lancs, March 9, 1925.

PREVENTION OF CORROSION.

TO THE EDITOR OF ENGINEERING.

SIR,—Whilst Mr. Evans in his letter, published in your issue of March 6 (page 298 *ante*), would seem to deny the possible truth of my suggestions regarding the prevention of corrosion, he nevertheless appears to admit their correctness. He writes that it is the *distribution* of the oxygen that does the damage. The rusting of a ferrous material lowers the P_H in its immediate vicinity, thereby creating a corrosion-resisting film. As a regular supply of oxygen could not fail to disturb the mobile material and so destroy the film having a lowered P_H, a greater rate of corrosion due to the larger supply of oxygen does not necessarily disprove my previous statements.

Furthermore, Mr. Evans writes that, in liquids on the alkaline side of P_H 9·5, the corrosion rate falls off with increasing alkalinity; I might suggest that, with increasing alkalinity, the P_H falls and, as I previously suggested, corrosion falls off, as stated by Mr. Evans.

With increasing acidity, the P_H falls, but then, not "corrosion proper," but the substitution of metal for hydrogen, takes place, *i.e.*, the action is not one of oxidation, but substitution. I would add that when alkalis are added to water in quantities to remove scale-forming salts, too much alkali is admittedly as great an evil as too much calcium bicarbonate, &c. For instance, if soda ash, to be used to assist in loosening the scale in a boiler, is allowed to remain *en masse* on the bottom of the boiler, the plates beneath the alkali will soon be eaten through.

Yours, &c.,
J. VERNON SHAW.

Warrington, March 9, 1925.

THE PROPERTIES AND STRUCTURE OF QUARTZ.

TO THE EDITOR OF ENGINEERING.

SIR,—In the account which you published on February 27 (page 266 *ante*) of a lecture that I gave at the Royal Institution on February 19, there is a passage which shows that I did not make myself sufficiently clear.

When quartz cools down through the critical temperature of 575 deg. C., it loses a certain amount of symmetry. High-temperature quartz, or β-quartz as it is sometimes called, may be either right- or left-handed; it can rotate the plane of polarisation of light to the right or to the left. But it shows neither piezo-electricity nor pyro-electricity: it is too symmetrical for that. Low-temperature or α-quartz, the ordinary form, is less symmetrical than the other because it possesses electric axes and the piezo- and pyro-properties; and these may have one or other of two opposite orientations. When the β-form turns into the α form it may, therefore, so to speak, get down on either side of the fence. If the change into one of the alternative forms takes place in some parts of the crystal, and into the other form in other parts, the result will be a twinned crystal, all right-handed or all left-handed, as the case may be, but differing in the sense in which piezo- and pyro-electricity can be developed. That the two varieties exist so naturally side by side is probably due to the fact that the movements of the atoms during the change from β to α is very small. There is naturally much interpenetration, and the evidence of the existence of both varieties is found all over the crystal.

The twinning of right-handed with left-handed quartz is another matter. It is the only kind which can occur in the β form. It may take place in either of two ways. In the first the fundamental lattices of the two kinds are oriented in the same way; and because the two can fit into each other in various directions—this can be seen from a study of the structure suggested by the X-ray analysis—the twinning, in this case, is also of the interpenetrating kind.

If a β-crystal twinned in this way cools down, there will arise two further possibilities: the right-handed and the left-handed portions may—to extend the previous analogy—get down on the same side of the fence, or on opposite sides. One of these leads to the well-known Brazilian twinning: the other to a less common form.

One other form of twin completes the list: it is found in France and in Japan. Two quartz prisms are stuck together almost at right angles. A glance at the X-ray model suggests an explanation. A right-handed quartz can be made to fit with a left-handed quartz across the plane of twinning in question; but as the adjustment of the two pieces in this particular way can take place across this plane only, there is now no interpenetration.

The twinning of quartz is a complicated but interesting phenomenon. I hope the length of this letter is justified by the interest, and at the same time is sufficient to show how the complication can be unravelled by a study of the structure.

Yours faithfully,
W. H. BRAGG.

The Royal Institution, London, March 9, 1925.

BOOKS RECEIVED.

Building Construction Plates. For Students and Others. By A. BUCHANAN and W. H. HUDSON. Part I. *Elementary Course.* [Price 5*s.* net.] Part II. *Advanced Course.* [Price 5*s.* 6*d.* net.] London: B. T. Batsford, Limited.

The Association of Engineering and Shipbuilding Draughtsmen. Foundry Practice for Draughtsmen. By M. WARNOCK. [Price 2*s.*] *The Involute and Barrel Types of Stator Winding for A.C. Electric Generators.* By R. SMALLWOOD. [Price 2*s.*] London: Offices of the Association.

Sell's Directory of Registered Telegraphic Addresses, 1925. Founded by HENRY SELL. London: Business Directories, Limited. [Price 45*s.* net.]

Taschenbuch der Kriegsflotten, 1924–25. Edited by B. WEYER. Munchen: J. F. Lehmanns. [Price 10 marks.]

Der Bau der Starrluftschiffe. Ein Leitfaden für Konstrukteure und Statiker. By JOHANNES SCHWENGLER. Berlin: Julius Springer. [Price 4·80 gold marks.]

United States Bureau of Mines. Annual Report by the Director of the Bureau of Mines to the Secretary of the Interior, June 30, 1924. [Price 10 cents.] Technical Paper No. 351. *The Electrical Manufacture of Carbon Black.* By J. J. JAKOSKY. [Price 10 cents.] No. 371. *Coke-Oven Accidents in the United States during the Calendar Year* 1923. By W. W. ADAMS. [Price 5 cents.] Washington: Government Printing Office.

United States Bureau of Standards. Technologic Papers No. 267. *Effect of Hot-Rolling Conditions on the Physical Properties of a Carbon Steel.* By J. R. FREEMAN and A. T. DERRY. Washington: Government Printing Office. [Price 10 cents.]

Aeronautical Research Committee. Reports and Memoranda No. 918. *The Strength of Struts: A Review of Progress Made in Theory and Experiment during the War.* By R. V. SOUTHWELL. [Price 1*s.* 6*d.* net.] No. 939. *On the Effect of Inertia on the Lateral Motion of an Aeroplane under the Influence of Gusts and Control Movements.* By L. W. BRYANT, B.Sc., and D. H. WILLIAMS, B.Sc. [Price 6*d.* net.] London: H.M. Stationery Office.

Electrical Engineering. By L. A. HAZELTINE. New York: The Macmillan Company; London: Macmillan and Co., Limited. [Price 30*s.* net.]

The Theory and Design of Structures: A Textbook. By EWART S. ANDREWS, B.Sc. Fourth Edition. London: Chapman and Hall, Limited. [Price 13*s.* 6*d.* net.]

SHIPS' LIFE-SAVING APPLIANCES.—The Mercantile Marine Department of the Board of Trade has issued circular 1654, entitled "Instructions to Surveyors," which contains information on the rules with regard to buoyant apparatus for foreign-going and home-trade passenger ships coming into force on July 1, 1925. Modifications have been made in the existing demands contained in "Instructions as to the Survey of Life-Saving Appliances" with regard to foreign-going vessels, details of which are available in the latest leaflet. This may be obtained from H.M. Stationery Office, Adastral House, Kingsway, London, W.C.2, price 1*d.*

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Production Costs.—The deputation of leading industrialists which the Chancellor of the Exchequer is to receive to-morrow on the subject of income-tax reduction has the strongest possible support from this district. The urgency of reducing production costs by pruning the major standing charges becomes more and more apparent with the repeated failure of manufacturers to attract sufficient new business in place of expiring contracts to keep running economically plants which of recent years have been so greatly extended. The receipt of fairly substantial orders on home account has recently brought a certain measure of relief, but taking into consideration current facilities for increased production, this has failed to compensate for the continued shortage of export business. Staffs have been kept employed at great sacrifice on the part of the leading concerns, but as there is obviously a limit beyond which this policy cannot be pursued, manufacturers stress the necessity of placing quotations upon a more attractive basis in comparison with those of foreign competitors.

Iron and Steel.—Conditions in heavy steel and pig-iron are far from satisfactory. Orders can be met from a gross production that has been further restricted by the closing of furnaces. The volume of business is less, in the aggregate, than was the case two months ago. As far as this section of the staple trades is concerned, optimistic forecasts prove to have been badly founded. The outlook offers no reliable indication of an early improvement. Similarly, business in iron and steel scrap is very patchy, prices showing frequent variation in response to the quickly changing mood of the market. The character of the current demand for ferro-alloys throws a dismal light on the state of the special steel trade. Business in high-speed steel alloys is restricted to the minimum. Curtailment of output of ferro-silicon has given an impetus to quotations for special deliveries. Railway departments continue to occupy a strong position, and though business is mainly confined to meeting the requirements of British railways, the outlook in the overseas markets seems to be brightening. Owing to the unsatisfactory position of the export trade, collieries are displaying little inclination to put in hand repairs to and renewals of wagons. A branch experiencing activity on home account, however, is that engaged on the manufacture of automobile steel. Implement and machinery makers are making somewhat better progress, while business in agricultural and garden tools tends to expand. Builders' and general ironmongery is in better demand, and there are numerous inquiries in circulation for pit-head gear and mining requisites.

South Yorkshire Coal Trade.—The position continues unsatisfactory, and, on balance, displays further weakness. An active demand for steam fuel is maintained on home account, though overseas requirements show a further falling-off. Cobbles and nuts are finding a better outlet, but buyers of all grades of slacks seem reluctant to commit themselves for future supplies. Despite the fact that a revival has been experienced in house coal, the market generally is only moderate. Foundry and furnace coke make no headway, rates showing a downward tendency. Quotations:—Best branch hand-picked, 30*s.* to 33*s.*; Barnsley best Silkstone, 26*s.* to. 28*s.*; Derbyshire best brights, 26*s.* to 31*s.*; Derbyshire best house 24*s.* to 26*s.*; Derbyshire best large nuts, 22*s.* 6*d.* to 25*s.*; Derbyshire best small nuts, 14*s.* to 16*s.*; Yorkshire hards, 18*s.* to 22*s.*; Derbyshire hards, 18*s.* 6*d.* to 22*s.*; rough slacks, 10*s.* to 12*s.* 6*d.*; nutty slacks, 8*s.* 6*d.* to 10*s.*; and smalls, 4*s.* to 6*s.* 6*d.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—The statistical state of Cleveland pig-iron continues healthy; stocks are small, but values are distinctly easy. Customers are still pursuing a cautious policy. Not only are they disinclined to commit themselves ahead to any extent, but they are seeking and securing price concessions, though market quotations are declared to be already on a level that barely covers cost of production. Home requirements fall short of what could be wished for, and Continental demand is on a very limited scale, but fairly good sales to Scotland are reported, largely through merchants. No. 1 is quoted 83*s.*; No. 3, g.m.b., 78*s.*; No. 4 foundry, 77*s.*; and No. 4, forge, 76*s.*

Hematite.—Producers of East Coast hematite are still hampered by rather heavy unsold stocks, and are anxious to make sales, but they are very reluctant to lower quotations, though buyers are disinclined to pay recognised market rates, which stand at 85*s.* 6*d.* for No. 1 and 85*s.* for mixed Nos.

Foreign Ore.—The position as regards foreign ore has undergone no change. So far as is ascertainable, transactions are still confined to sales of odd cargoes. It is difficult to discover on what terms contracts might be arranged, but sellers still base quotations on best Rubio at 22*s.* 6*d.* c.i.f. Tees.

Blast-furnace Coke.—Durham blast-furnace coke is in only moderate request. Good average qualities run from 23*s.* 6*d.* to 24*s.*, delivered to users' works here.

Manufactured Iron and Steel.—Sales of finished iron and steel are difficult to arrange. Continental competition is keen and producers here are unable to sell at anything like the figures foreigners name in some markets. To home customers, common iron bars are 12*l.*; iron rivets, 14*l.* 5*s.*; packing (parallel), 8*l.*; packing (tapered), 11*l.* 10*s.*; steel billets (soft), 8*l.* 10*s.*; steel billets

(medium), 9*l.*; steel billets (hard), 9*l.* 10*s.*; steel ship, bridge and tank plates, 9*l.* 5*s.*; steel angles, 9*l.* to 9*l.* 5*s.*; steel joists, 9*l.* to 9*l.* 5*s.*; heavy sections of steel rails, 9*l.* to 9*l.* 10*s.*; black sheets (24 in. gauge), 12*l.*, and galvanised corrugated sheets (24 in. gauge), 16*l.* 10*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—No change of any note has taken place in the Scottish steel trade during the week, and producers are as hard up for orders as ever. The demand from all sources continues poor, and specifications against contracts are being given out very slowly. Inquiries for almost all classes of material are far from satisfactory, with the result that the outlook is none too good. Deliveries from the Continent are not as heavy as they were, but where consumers have to quote so keenly to secure business they are, in many cases, almost forced to use even a proportion of the foreign material, as the saving is in the neighbourhood of a pound or two per ton. Ship plates and sections are particularly slow of sale, and nothing short of a boom in the shipyards will lift them out of their present lowly position. Prices are nominally unchanged.

Black Sheet Trade Prices Reduced.—Business in the the black sheet trade has recently been fairly good, but all sections of the industry have not participated. Galvanised sheets have, perhaps, been about the best, whereas heavy-gauge sheets have been in very poor demand. There is quite a fair amount of work on hand, but to stimulate forward business a reduction of 20*s.* per ton on heavy-gauge sheets, and 25*s.* per ton on the lighter gauges has been agreed upon by producers. The new prices which have now come into force are as under: Sheets, ⅛ in., 10*l.* 10*s.* per ton; ¼ in., 11*l.* per ton; 12 to 16 g., 12*l.* per ton; 17 to 20 g., 12*l.* 5*s.* per per ton, 21 to 24 g. 12*l.* 15*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—In the West of Scotland malleable iron trade the position is practically without change. Much plant is idle, and as hand-to-mouth conditions are all too common, makers are finding it very difficult to keep running. The steel-bar branches are not doing too well either at the moment. The price of "Crown" bars is steady.

Scottish Pig-Iron Trade.—The demand for Scottish pig-iron has not improved yet, and there hardly seems to be any prospect of an improvement in the near future. The output is on the minimum scale and stocks on hand are more than equal to all the calls being made. Hematite is particularly slow owing largely to the quietness at the local steel works, and foundry grades are also in poor request. Foreign business has fallen off to a considerable extent and inquiries are not coming forward for anything approaching the old tonnages. The recent easing of quotations has failed to stimulate business up to the present.

Scottish Pig-Iron Shipments.—The shipment of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, March 7, amounted to 825 tons. Of that total 780 tons went overseas and 45 tons coastwise. For the corresponding week of last year the figures were 251 tons overseas and 174 tons coastwise, making a total shipment of 425 tons.

CHEMICAL ENGINEERING AND CHEMICAL CATALOGUE.—Described as a work of technical reference for all production industries and published by Mr. Leonard Hill, of 173, Fleet-street, London, E.C.4, the Chemical Engineering and Chemical Catalogue for 1925, a first issue, consists partly of an alphabetical list of products associated in each case with the names of makers and references to the succeeding part of the volume. This latter section supplies all particulars regarding the location of the different firms, their telegraphic addresses, &c., and includes descriptions of the different materials manufactured by them, fully illustrated in many cases. In a final index the different industries are classified and references to the chemicals and plant used are given. The book contains much general information and should prove useful to the chemical trade.

TENDERS.—The Department of Overseas Trade of 35, Old Queen-street, London, S.W.1, have announced that the Direction Générale des Chemins de fer d'Anatolie are calling for tenders for the reconstruction of ten iron bridges on the Haidar Pacha-Eski Chehir section of the Anatolian Railway. The adjudication will take place on April 2, 1925.—The municipal authorities at Antwerp are requesting offers for the supply and erection of an electric motor and centrifugal pump. These tenders must reach Antwerp by April 2, 1925.—The Municipality of Copenhagen have announced that a competition for a highway bridge over Copenhagen Harbour is about to be held.—The Egyptian Ministry of the Interior invite tenders for the supply of goods required by the Prisons Department for the year 1925-26. Offers must reach the Inspector-General of Prisons, Cairo, not later than 12 noon on May 5, 1925.—Tenders will be received in Santiago, Chile, until 3 p.m. on May 14, 1925, by the Inspeccion-General de Hidraulica for the supply, delivery, and erection of four electrically operated cranes each of 3 metric tons capacity and one similarly operated crane of 20 metric tons capacity. United Kingdom firms in a position to supply materials may obtain further particulars regarding these requests for tenders from the Department of Overseas Trade.

NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS. To-night at 6 p.m., at Storey's-gate, S.W.1. Extra General Meeting. Reports to the Cutting Tools Research Committee: "The Action of Cutting Tools," by Professor E. G. Coker, D.Sc., F.R.S., and "Experiments with Lathe Tools on Fine Cuts, and some Physical Properties of the Tool Steels and Metal Operated Upon," by Mr. Dempster Smith, M.Sc., and Mr. Arthur Leigh, B.Sc. Friday, March 20, at 6 p.m. Second Report of the Marine Oil-Engine Trials Committee.

THE JUNIOR INSTITUTION OF ENGINEERS.—To-night, at 7.30 p.m., at 39, Victoria-street, S.W.1. Lecturette: "Notes on Methods of Producing Modern High-grade Machine Tools," by Mr. A. P. Bale, M.I.Mech.E. Friday, March 20, at 7.30 p.m. Ordinary Meeting. "Modern Transport," by Mr. S. H. Hole.

THE INSTITUTION OF CIVIL ENGINEERS: NEWCASTLE-UPON-TYNE ASSOCIATION.—Monday, March 16, at 7.30 p.m., in the Lecture Theatre, Mining Institute, Neville Hall, Newcastle-upon-Tyne. "Coal Shipping Staiths; Their Lay-out, Construction and Operation," by Mr. J. Taylor Thompson.

THE BRADFORD ENGINEERING SOCIETY.—Monday, March 16, at 7.30 p.m., at the Bradford Technical College, Great Horton-road, Bradford. Lecture: "The Steam-Ejector Air Pump, and its Applications," by Prof. G. F. Charnock, M.Inst.C.E.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Tuesday, March 17, at 5.15 p.m., at Albemarle-street, W.1. "Evolution of the Scientific Instrument" (Lecture II), by Professor E. N. da C. Andrade. Friday, March 20, at 9 p.m., Evening discourse, by Prof. J. W. McBain. "Soaps and the Theory of Colloids." Saturday, March 21, at 3 p.m., Afternoon Lecture. Sir Ernest Rutherford. "The Counting of the Atoms." (Lecture IV.)

THE INSTITUTE OF TRANSPORT.—Tuesday, March 17, at 5.30 p.m., at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C. 2. Graduates' and Students' Meeting. Lecture: "Some Practical Statistical Units," by Mr. A. E. Kirkus.

THE INSTITUTE OF MARINE ENGINEERS.—Tuesday, March 17, at 6.30 p.m., at 85-88, The Minories, Tower-hill E.1. "Motor Passenger Vessels," by Mr. A. C. Hardy, B.Sc.

THE SOCIETY OF GLASS TECHNOLOGY.—Wednesday, March 18, at 2.30 p.m., at the Armstrong College, Newcastle-upon-Tyne. "The Use of Zirconia in Glass Making and the Characteristics which this Substance imparts," by Miss V. Dimbleby, B.Sc. Mr. S. English, M.Sc. Miss E. M. Firth, B.Sc. Mr. F. W. Hodkin, B.Sc. and Prof. W. E. S. Turner, D.Sc. "The Effect of Composition on the Viscosity of Glass. Part III. Soda-Lime-Magnesia Glasses and Soda-Lime-Alumina Glasses," by Mr. S. English, M.Sc. "Further Studies on the Influence of Boric Oxide on the Properties of Glass" by Mr. F. Winks, B.Sc., and Prof. W. E. S. Turner, D.Sc.

THE BRITISH COLD STORAGE AND ICE ASSOCIATION.—Wednesday, March 18, at 5.30 p.m., at the Royal Society of Arts, John-street, Adelphi, W.C.2. "Small Refrigerating Plants, and the Thermodynamical Properties of Refrigerating Liquids," by Dr. Ezer Griffiths and Mr. J. H. Awbery, B.A., B.Sc.

THE INSTITUTION OF CIVIL ENGINEERS.—Wednesday, March 18, at 6 p.m., at Great George-street, S.W.1. Students' Meeting. "The Littoral Drift of Shingle," by Mr. Thomas William Marsh, B.Sc.

THE INSTITUTE OF METALS: NORTH-EAST COAST LOCAL SECTION.—Wednesday, March 18, at 7.30 p.m., at Armstrong College, Newcastle-upon-Tyne. "Electric Furnaces," by Mr. A. Glynne Lobley, M.Sc.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, March 18, at 7.30 p.m., at 49, Cromwell-road, South Kensington, S.W. 7. "The Energy of Saturated Air in a Natural Environment," by Sir Napier Shaw, F.R.S., and Mr. H. Fahmy, D.I.C. "On the Relation between the Source of the Air and the Upper Air Temperature up to the Base of the Stratosphere," by Mr. C. K. M. Douglas. "Waves at an Approximately Horizontal Surface of Discontinuity in the Atmosphere," by Mr. A. H. R. Goldie.

THE ROYAL SOCIETY OF ARTS.—Wednesday, March 18, at 8 p.m., at John-street, Adelphi, W.C.2. Ordinary Meeting. "The Friese-Greene Process of Colour Cinematography," by Mr. Claude N. Friese-Greene.

THE ROYAL AERONAUTICAL SOCIETY.—Thursday, March 19, at 5.30 p.m., at Albemarle-street, W.1. Lecture "Practical Navigation of Aircraft," by Captain F. Tymms.

THE INSTITUTION OF MINING AND METALLURGY.—Thursday, March 19, at 5.30 p.m., at the Geological Society, Burlington House, Piccadilly, W.1. "Notes on Ore-sorting and Hand-picking," by Mr. Ernest R. Woakes. "Mining and Metallurgical Practice in South Africa." "Notes on Deep-level Winding," by Mr. J. A. Vaughan, M.Inst.C.E., M.I.Mech.E. "Gold Metallurgy in the Union of South Africa," by Mr. H. A. White. "Ventilation as an Agent in the Prevention of Miners' Phthisis on the Witwatersrand," by Mr. C. J. Gray.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, March 19, at 6 p.m., at Savoy Place, Victoria Embankment, W.C.2. "Permanent Magnets in Theory and Practice" (Second Paper), by Mr. S. Evershed. Preceded by presentation of the Faraday Medal to Sir J. J. Thomson, M.A., O.M., F.R.S.

THE INSTITUTION OF MECHANICAL ENGINEERS: MIDLAND BRANCH.—Thursday, March 19, at 6.30 p.m., at the Queen's Hotel, Birmingham. Address on "The Engineers' Prospects after 1815 and 1918," by Mr. John W. Hall.

THE BIRMINGHAM METALLURGICAL SOCIETY.—Thursday, March 19, at 7.15 p.m., at the Chamber of Commerce, New-street. Lecture: "Aluminium," by Mr. G. B. Brooke, F.I.C.

THE INSTITUTE OF METALS: LONDON LOCAL SECTION.—Thursday, March 19, at 7.30 p.m., at the Institute of Marine Engineers, 85-88, The Minories, Tower-hill, E.1. Discussion on "Progress in the Practical Application of Non-ferrous Alloys" will be opened by Dr. G. H. Gulliver.

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Thursday, March 19, at 7.30 p.m., in the Lecture Theatre, Literary and Philosophical Society, Newcastle-upon-Tyne. "Seaworthiness," by Mr. B. J. Ives.

THE INSTITUTION OF MECHANICAL ENGINEERS: YORKSHIRE BRANCH.—Friday, March 20, at 7.30 p.m., at the Brown-Firth Research Laboratories, Sheffield. "Steel Construction as Applied to Steelworks and Mill Buildings," by Mr. A. A. Fordham.

THE HULL ASSOCIATION OF ENGINEERS.—Saturday, March 21, at 7.15 p.m., at the Hull Technical College. Lecture, "Steam Turbines," by Mr. Elce, M.Sc.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Mr. W. North Lewis and Mr. Edmund L. Hann were at the annual general meeting of the Monmouthshire and South Wales Coalowners' Association, held at Cardiff yesterday, appointed chairman and vice-chairman respectively for the ensuing year. Mr. Lewis is chairman and managing director of Insoles, Limited, and chairman of the Windsor Steam Coal Company, Limited. Mr. Hann is the general manager of the Powell Duffryn Steam Coal Company, Limited. It was reported that the output of collieries controlled by members of the association, numbering 119, in 1924 amounted to 47,328,446 tons, or 3,129,418 tons less than the assured output, the contribution of the Cardiff Board being 29,224,523 tons, the Newport Board 12,125,082 tons, and the Swansea Board 5,978,841 tons. The assurances for the year 1925–26 were given as 49,880,376 tons, the Cardiff Board assuring 30,413,250 tons, the Newport Board 13,379,903 tons, and the Swansea Board 6,087,223 tons, the total being 3,204,625 tons below the assurances in the previous year. No improvement has taken place in the condition of the steam coal trade. In fact, the prospects are more discouraging for during the week it was reported that the French State Railways, who take from 150,000 to 200,000 tons of Welsh coal each quarter, had placed orders for 100,000 tons of small and 40,000 tons of large with French collieries and would not be taking anything from South Wales over the next three or six months. The Paris–Orleans Railway, which takes about 40,000 tons of Welsh coal in each three months too, has decided not to take Welsh coal for the next few months; while the Italian State Railways, another good customer for Welsh coal, are reported to have made arrangements with the German Government for increased supplies of German coal. At present the Welsh collieries are not working on the average more than 4½ days a week, and even so salesmen experience difficulty in securing orders to keep the collieries going, despite the fact that prices are at the lowest levels touched for a couple of years. Best Admiralty large coal rules from 26*s.* to 27*s.*, with seconds from 24*s.* 6*d.* to 25*s.* 6*d.*, and Monmouthshires from 23*s.* 6*d.* to 24*s.* 6*d.*, while dry large is in very poor request at 23*s.* 6*d.* to 25*s.* 6*d.* Sized coals too are quiet, washed dry nuts ruling from 24*s.* 6*d.* to 28*s.*, with bituminous nuts extremely quiet at 19*s.* to 20*s.* Steam smalls, despite the fact that an increasing proportion of outputs are being used under colliery boilers, are freely available at 15*s.* to 15*s.* 6*d.*, with cargo smalls from 12*s.* to 14*s.* Exports of coal and coke from South Wales in the four weeks ended February 22 amounted to 2,340,999 tons, or 246,756 tons more than in the preceding month, while shipments of patent fuel reached 85,189 tons, a reduction of 5,259 tons.

Iron and Steel.—Exports of iron and steel goods from South Wales in the past week totalled 6,090 tons, compared with 8,420 tons in the preceding week. Exports of tinplates and terneplates totalled 3,045 tons against 7,017 tons, black plates and sheets 1,314 tons against 577 tons, galvanised sheets 1,541 tons against 529 tons, and other iron and steel goods 192 tons against 295 tons. Continental and home demand is generally improving.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—The seventh ordinary meeting of the present session of the Institution of Electrical Engineers (Scottish Centre) will be held on Friday, April 24, at 2.15 p.m., in the Electrical Engineering Department of the Technical Institute, Bell-street, Dundee. Arrangements will be made before the meeting for lunch at the Royal Hotel, Dundee. The Lord Provost and magistrates of the city will hold a reception of members attending the meeting at 7 p.m. in the Art Galleries at the Albert Institute, while on Saturday, April 25, char-a-bancs will depart from these buildings at 10.20 a.m. for a tour of the neighbourhood. Persons desirous of taking part in these functions should communicate with Mr. W. Frain, Hon. Secretary, 38, Nethergate, Dundee.

CROSS OIL-CRACKING PLANT FOR THE MEDWAY OIL AND STORAGE CO., LIMITED.

(*For Description see Page* 312.)

FIG. 15. OIL-HEATING FURNACES.

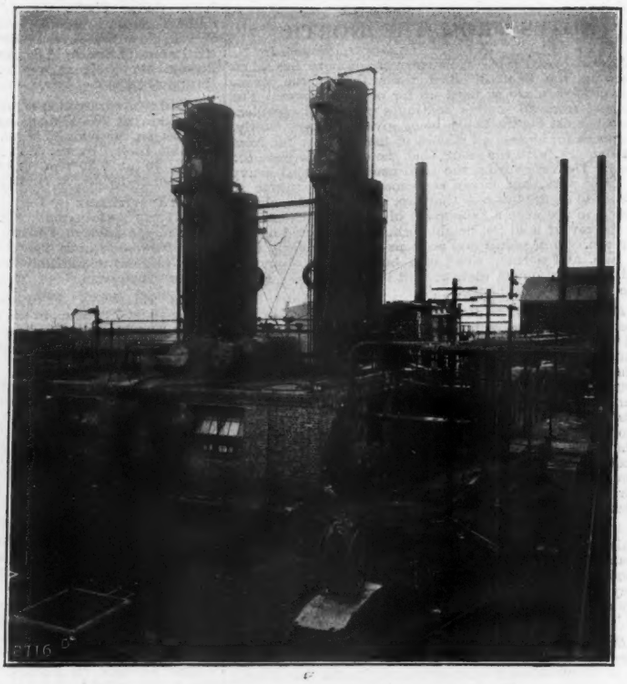


FIG. 16. CRACKING UNITS FROM CONTROL-HOUSE END.

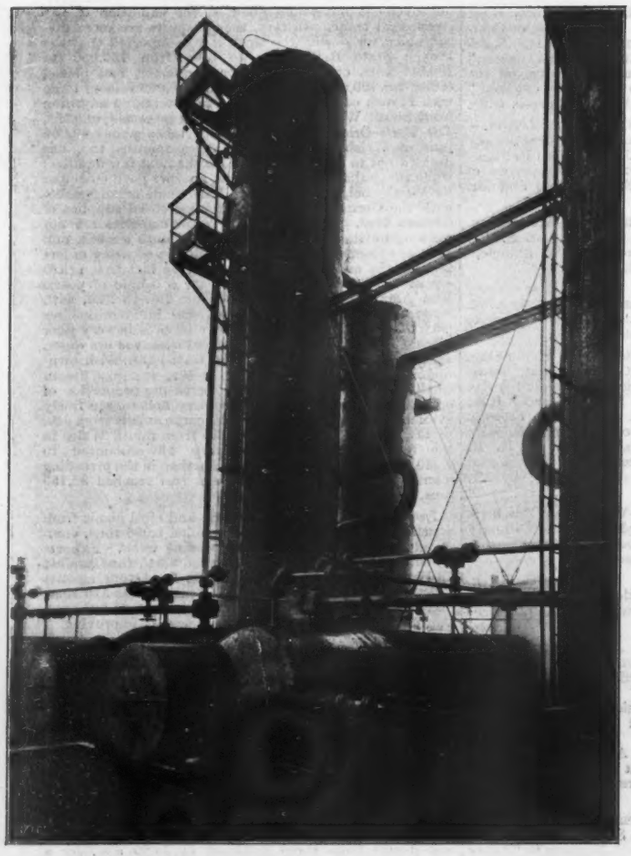


FIG. 17.

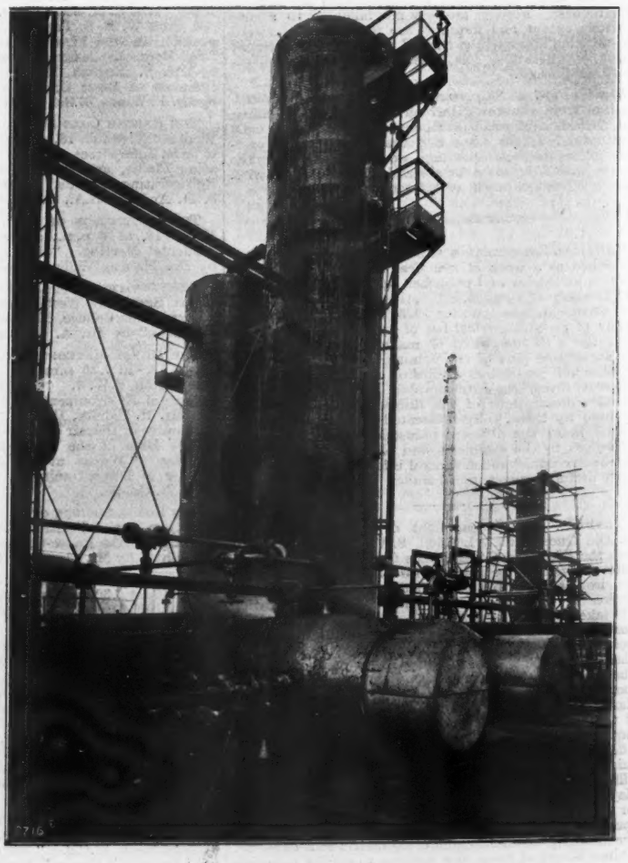
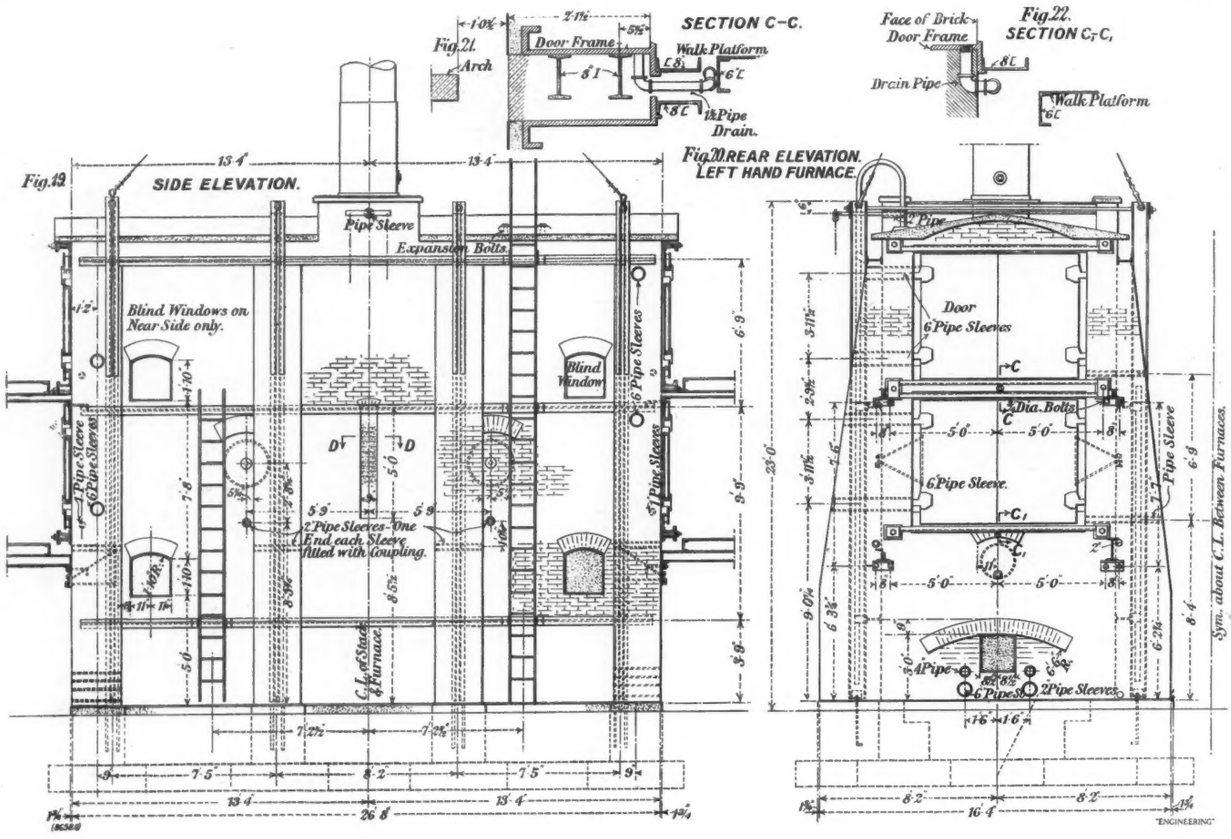


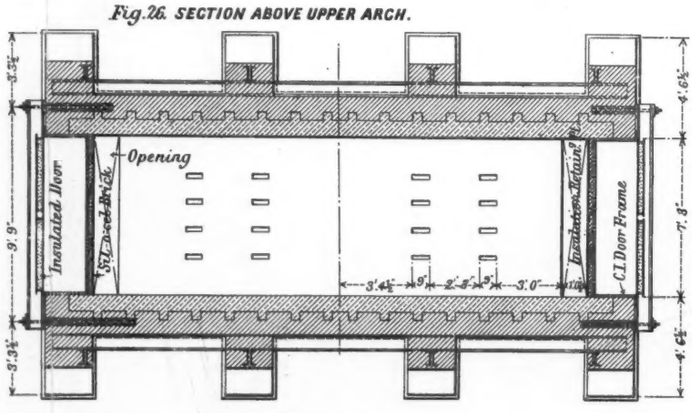
FIG. 18.

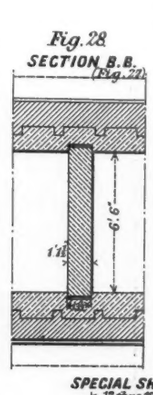
FIGS. 17 AND 18. DEPHLEGMATING TOWERS, EVAPORATORS AND OUTLET ENDS OF REACTION CHAMBERS.

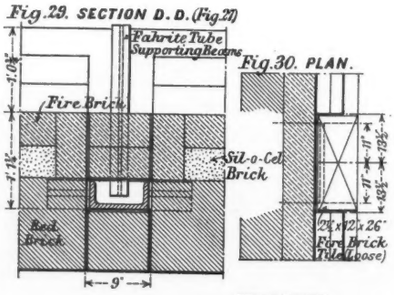
COMPONENTS OF CROSS OIL-CRACKING PLANT FOR THE MEDWAY OI

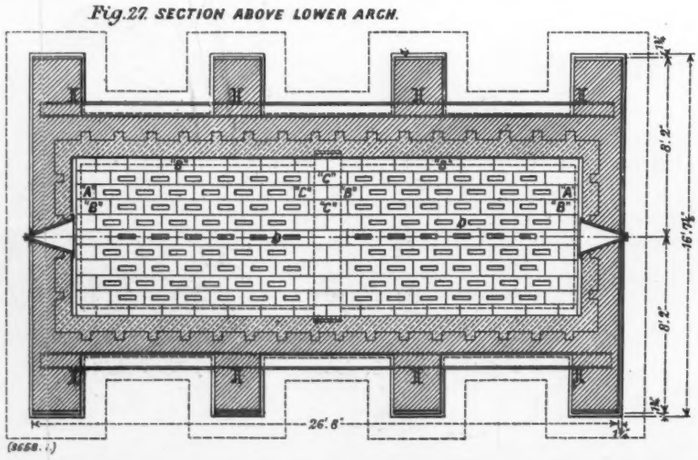
(For Description see Page

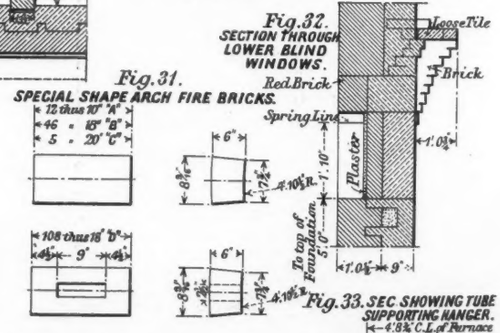












EDWARDS OIL AND STORAGE COMPANY, LIMITED, ISLE OF GRAIN, KENT.

(For Description see Page 312.)

Fig. 23.

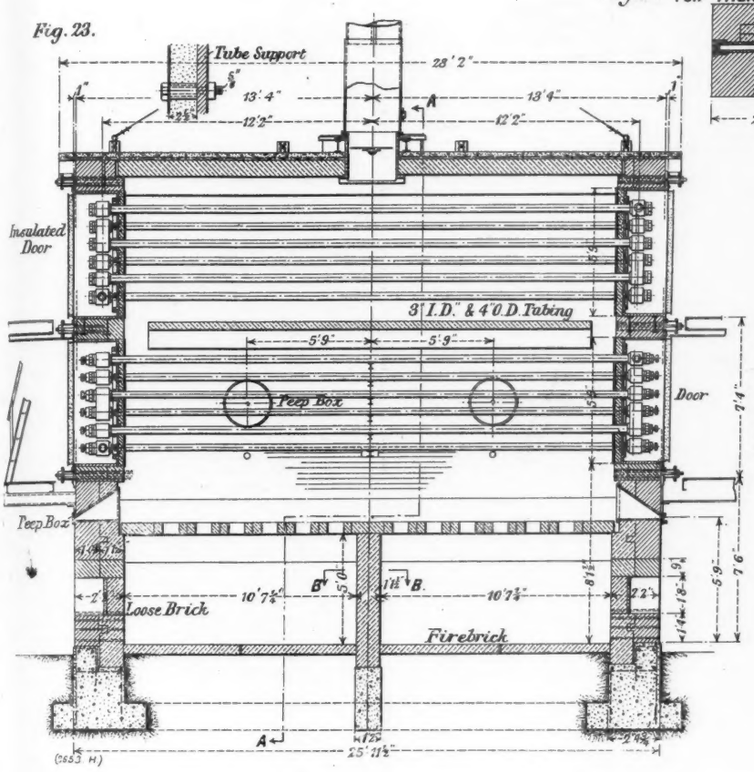


Fig. 25. PIPE SLEEVE DETAIL FOR THERMO-COUPLE

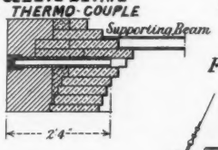


Fig. 24. SECTIONAL ELEVATION A.A.

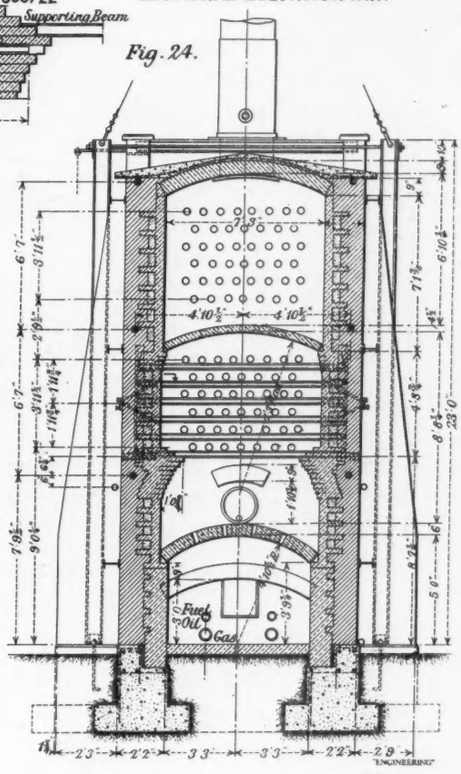


Fig. 35. DETAIL OF FURNACE TUBES AFTER BEING ROLLED & BEADED IN PLACE.

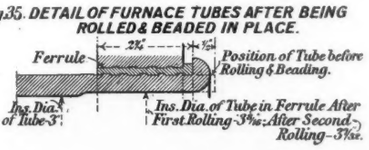

Ferrule
Position of Tube before Rolling & Beading.
Ins. Dia. of Tube 3"
Ins. Dia. of Tube in Ferrule After First Rolling 3 9/16"; After Second Rolling 3 5/16"

Fig 36

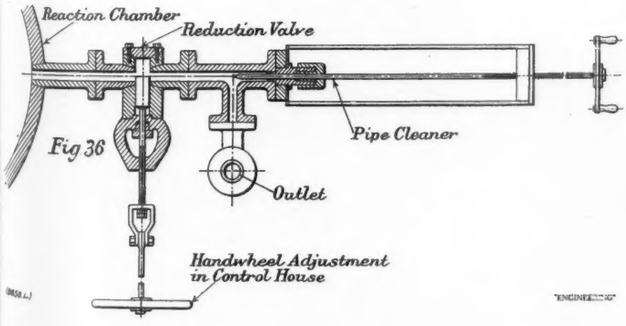


Fig. 37.

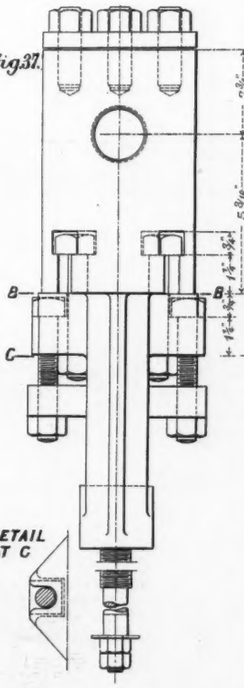


Fig. 38.

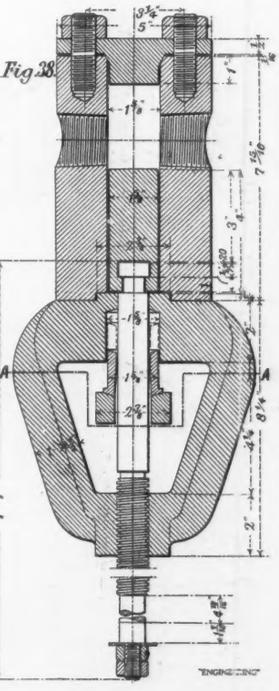


Fig. 41.

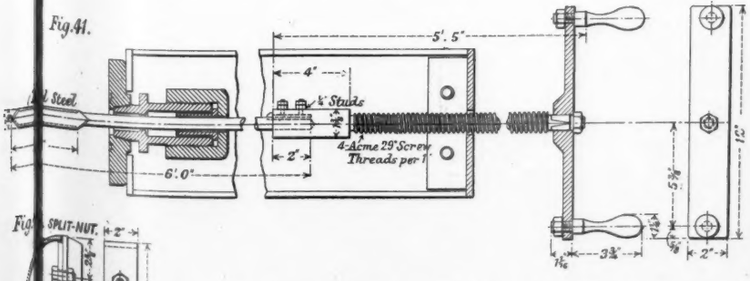


Fig. 39.

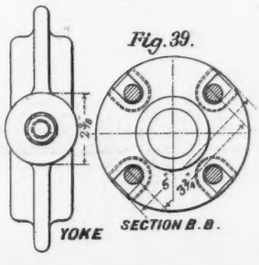


Fig. 40. SECTION A.A

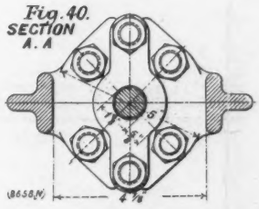
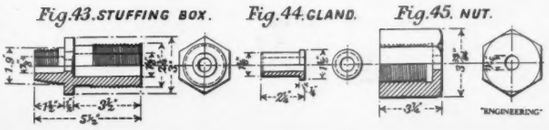


Fig. 43. STUFFING BOX. Fig. 44. GLAND. Fig. 45. NUT.



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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received 10 days previous to the day of publication.

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ENGINEERING.

FRIDAY, MARCH 13, 1925.

CARBURETTOR DESIGN.

ATTENTION has been drawn with sufficient frequency in the past few years to the importance of conserving the world's power resources, and the rapid increase in the use of the high-efficiency internal-combustion engine has been received with satisfaction for this reason. It is probable, however, that a considerable waste in the aggregate results from the enormous number of small oil engines in use in motor vehicles, a large percentage of these engines undoubtedly being inefficient. Once a motor vehicle has left the maker's hands, very little effort is generally made on the part of the user to retain the engine efficiency at anything approaching the original figure, and as a result very large numbers are running at efficiencies up to 50 per cent. below that which could be obtained with correct carburettor settings. As the majority of these engines are in the hands of people who will not go to the trouble and expense of having them tuned up, the only remedy would appear to lie in stimulating their interest in the subject by the imposition of a fuel tax, a procedure to which we have recently referred as presenting great practical difficulties. On the other hand, many cars are fitted in the first instance with carburettors which are not as efficient as they might be when the engine leaves the works, an over-rich mixture offering a tempting solution to many carburation difficulties. In general, the number of attempted solutions of a problem offers an index to its inherent difficulty, and the fact that eleven hundred different carburettors have been patented in the United States, and four thousand in the British Isles, suggests that the carburation problem is one of the most difficult that has to be overcome by engineers in the course of their work. The conditions which should be fulfilled by a carburation system are to some extent a matter of opinion, and this consideration combined with the possibility of alternative solutions to the same problem, accounts to some extent for the diversity of carburettor types put on the market. There can be little doubt that a very appreciable percentage of the patents referred to have been taken out by misguided enthusiasts who possess only a superficial knowledge of the issues involved, and the measure of success attained by some of the designs put forward is only explicable on the assumption of still greater ignorance on the part of the user.

In view of the complex nature of the problem of carburettor design, an authoritative review of the fundamental issues involved should be widely appreciated, and in a paper read by Mr. D. Finlayson before the Institution of Automobile Engineers, on Tuesday last, a summary of the results obtained by the Research Association of British Motor and Allied Manufacturers dealing with the process of carburation is given. In the case of motor-vehicle engines, economy in fuel consumption is only one of the desiderata in carburetter design, and an instrument which would supply the most economical mixture under all conditions would be highly unsatisfactory in other respects. Amongst other questions involved in the design, perhaps the most important is that of maximum power output, but, in addition, easy starting, slow running, good acceleration, and the possibility of valve burning may be mentioned. It is in the relative importance which should be given to these various factors that justifiable differences of opinion may exist, and as some of the considerations are conflicting an ideal carburettor is unattainable in practice.

Until recently it was generally supposed that if a carburettor was capable of supplying a constant air fuel ratio under all conditions it would meet all requirements, but it is now fully appreciated that the mixture ratio for maximum economy is not the same as that for maximum power. In his paper Mr. Finlayson gives a number of experimental results obtained in the laboratories of the Research Association, which show that the maximum power mixture is about 20 per cent. richer than that giving maximum economy; and that whereas the former is almost independent of load or speed, the latter becomes richer with decreasing load. Other results are quoted to show that on multi-cylinder engines the maximum economy mixture may be taken to vary directly with the induction pipe depression. The latter result gives a basis on which a maximum economy carburetter can be designed, and such an instrument would have a practically linear characteristic, the mixture strength steadily decreasing with increasing load. From what has already been said it will be clear that such a curve would have to be modified considerably to meet practical considerations. The establishment of an ideal characteristic is very important, as it is only by this means that the performance of existing carburetters can be satisfactorily computed, or the essential requirements of a new design established. As already stated, in actual practice it might be found necessary to depart very considerably from such an ideal curve, but this would not detract from the value of the latter as a basis of comparison. Any variation, however, should be capable of a rational interpretation. Mr. Finlayson suggests that the maximum economy curve should be modified to meet certain practical considerations in order to produce the ideal curve, but the exact nature of such modifications is somewhat controversial in the present state of knowledge, and it would therefore appear more logical to regard the maximum economy curve itself as the ideal. To illustrate our point we may take the modifications proposed by Mr. Finlayson. He suggests that means should be taken to enrich the mixture progressively after the point representing 80 per cent. to 90 per cent. of full load has been passed, and that at full load the mixture should have attained the strength corresponding to maximum power. At the same time it would be necessary to raise the mixture strength slightly above that giving maximum economy throughout the whole range in order to overcome starting, acceleration, and other difficulties. These modifications will admittedly give a curve which approximates more closely to actual conditions, but the exact position of the curve on the mixture strength scale cannot be given in the light of available data, and more than one speaker

taking part in the discussion suggested that a further modification was certainly necessary to meet starting and slow running requirements. Actual characteristics of a number of existing carburetters are given in the paper, and we believe it would have been more profitable to compare these with the maximum economy curve rather than with a possibly controversial ideal, as was done by Mr. Finlayson.

Probably the most valuable part of the paper is the investigation of the flow of fuels through a single jet and tube, rational formulæ being utilised to interpret accepted empirical results. As stated by one or two of the speakers joining in the discussion, the method of presentation renders it difficult for the engineer, as distinct from the physicist, to give a practical interpretation to the results, but the value of the latter can hardly be over-emphasised as a review of the present stage of knowledge on the fundamental considerations governing carburettor design.

From the information given, it is possible to estimate the probable behaviour of a given jet and tube under varying conditions with considerable accuracy, but our space will only permit of a brief reference to some of the results obtained. In the case of a single jet, experimental results are quoted to show the coefficient of discharge C in the usual formula $Q = CA\sqrt{2gh}$ can be expressed as a function of $\frac{v\,d\,\rho}{\mu}$, where v is the linear velocity of the fuel at some part of the jet, d is a linear dimension which distinguishes between the sizes of geometrically similar jets, ρ is the density and μ the viscosity of the liquid flowing through the jet. Similar relationships are known to exist for flow through thin orifices, and through long pipes, so that the relationship given appears to be general for all types of jet. The expression $f\left(\frac{v\,d\,\rho}{\mu}\right)$ is equivalent to $f\left(\frac{W}{d\,\mu}\right)$, where W is the mass rate of flow, and by plotting this function against the value of C calculated from the expression $Q = CA\sqrt{2gh}$, modified to correspond to carburettor conditions, the characteristic of the jet is obtained. In the case of jets of the usual type having an appreciable parallel portion constituting the opening, the characteristic shows a rapid, followed by a more gradual increase in the coefficient of discharge, but for jets of the orifice type the characteristics have a distinct maximum value. The effect of temperature on the mass flow of petrol through typical jets is shown to be small between the usual working limits; thus in the case of a parallel jet an increase in temperature from 0 deg. to 40 deg. C. results in a maximum variation of 5 per cent. At low heads and low rate of flow, increasing the temperature results in an increased rate of flow, but at high rates the reverse action takes place. The change over is accounted for by the dominant effect of viscosity at low rates, whereas density is the predominant factor at high rates. As would be anticipated from this, in the case of orifice jets the change over occurs much earlier. The effect of temperature is more pronounced in the case of fuels other than petrol, and would require consideration in the case of an alcohol carburettor, the difference in the mass rate of flow over the same temperature range being 30 per cent. with this fuel.

The author refers to the influence of induction pipe design on the problem of carburation, and the latter portion of his paper is devoted to the question of vapourisation, in which the shape and temperature of the induction pipe are controlling factors. There was a tendency in the discussion to introduce issues which were somewhat outside the scope of the paper, such as the actual design of the carburettor itself. The placing of the control of the mixture strength in the hands of the driver, frequently employed on American cars, was mentioned; but it appears most desirable, in view of the considerations that we gave at the outset, that the carburettor should be designed in such a way as to require a minimum of interference on the part of the actual user. In this connection, the present popularity of the type of carburettor which has only one moving part—the throttle—appears all to the good, and the provision of a much larger filter than that usually fitted would be a further step in the right direction, as tending to minimise the necessity for taking out and clearing the jets—a procedure which introduces the possibility of serious alterations in the hands of an ignorant owner.

THE ASSOCIATION OF TECHNICAL INSTITUTIONS.

WITH a few notable exceptions engineers do not appear to take any great interest in educational matters, and as a rule give but little assistance to the educationalists who are engaged in an important and difficult work. In a paper read by Mr. G. Mavor on the "Conditions of Training and Education of Apprentices," read at the annual general meeting of the Association of Technical Institutions on Saturday last, the author mentions that an appeal was sent out by the Council of the Association to the leading firms in numerous trades and to the national employers' federations; and that in the result, about 10 per cent. of the firms circulated troubled to reply. This figure applies to the whole of the trades approached, the actual figure in the case of the engineering trades only being 11·4 per cent. The appeal took the form of a questionnaire regarding the conditions of training and education in the trade concerned, and the failure of the remaining 88·6 per cent. of the engineering firms to send in a reply can only indicate a widespread indifference to the subject of the inquiry. This lack of interest on the part of employers is difficult to understand, as the prosperity of British engineering firms in the future depends on the efficiency of the education which the coming generation of engineers is now receiving. That the indifference to which we have referred is not shared by the Councils of the senior Institutions, as has been shown in a practical manner by the part that they have taken in the development of the schemes for national certificates and diplomas in engineering. Speaking at the luncheon of the Association of Technical Institutions on Friday, Sir John Dewrance aptly referred to the Institution of Mechanical Engineers itself as an educational institution, and mentioned that the Council take a close interest in the work of the Association. As a large percentage of the leading positions in the engineering industry must be held by members of the Institution, the small number of replies to the questionnaire to which we have referred suggest that the interest of the Council is not altogether shared by the bulk of the members. It is possible that the interest of the latter might be stimulated if papers specifically dealing with questions of engineering education were more frequently presented at the meetings. The recent correspondence in our columns regarding the Whitworth Scholarships does not reflect any general attitude of indifference, and suggests that the interest of the bulk of engineers in educational matters is rather dormant than non-existent, and can readily be aroused by a specific issue.

The inquiry of the Association was primarily concerned with the facilities afforded for the attendance at classes of young employees in the various trades, and it may have been thought that in the case of the engineering trades the question of training had been so thoroughly thrashed out in the past that there was little more to be said. If this is the explanation of the indifference shown, we believe the attitude to have been a mistaken one. The training in trades other than engineering is somewhat outside our scope, but in the case of the latter attention has been in general concentrated on the training of apprentices for the skilled trades, and the tendency has been for the education of the numerous employees who at the best will only become skilled in one operation to be neglected. As pointed out by Mr. Legros in his presidential address to the British Section of the Société des Ingénieurs Civils de France, the latter type of employee constitutes an ever-increasing proportion of the personnel of an engineering works, and the effort of the Association of Technical Institutions to include such workers in any scheme of education is therefore much to the point.

Of the other papers considered at the meeting, that read by Mr. J. E. Montgomrey on "The Working of the Schemes for National Certificates and Diplomas in Engineering" is of most interest to engineers. It will be recalled that this scheme was outlined by Dr. Hele-Shaw in his presidential address to the Institution of Mechanical Engineers in 1922. This address was reprinted in our issue of October 22, 1922, and we need not, therefore, refer to it in detail here. In his paper Mr. Montgomrey reviews the working of the scheme since its inauguration, and mentions that practically every technical college of considerable size, to which the scheme is applicable, is now included. In 1923 an arrangement was arrived at between the Institution of Mechanical Engineers and the Scottish Education Department, by means of which students at central institutions and continuation class centres in Scotland became eligible for the award. In the same year the Institution of Electrical Engineers adopted the scheme for electrical students, and in the past year an arrangement was concluded between the Institutions of Mechanical and Automobile Engineers for endorsement on behalf of the latter Institution of higher national certificates and diplomas in respect of automobile engineering subjects included in the final examination. The entire value of these awards depends on their recognition by engineering employers, and it is essential for the success of the scheme that the latter should have a clear idea of the standard represented. In this they should be assisted by the fact that the Council of the Institution of Mechanical Engineers accept the award as giving exemption from such subjects of the Associate Membership Examination as are covered by the final examination for the higher certificates or diplomas.

COUNTING THE ATOMS.

AT the Royal Institution on Saturday last Sir Ernest Rutherford delivered the second of his course of four lectures on the above subject.

In the last lecture he said he had described certain methods of deducing the number of the atoms and their dimensions from the kinetic theory and had pointed out that these were not capable of any great precision. The results obtained depended, in fact, a good deal on the way the data were dealt with. Thus, for the number of molecules in a cubic centimetre of air taken at normal temperature and pressure, Maxwell deduced the value $1{\cdot}9 \times 10^{19}$, Meyer about 1875 gave $6{\cdot}1 \times 10^{19}$, and Kelvin in his Baltimore lectures, as revised in 1900, gave 10×10^{19}. Kelvin, it might be added, was interested in making the number large. The accepted figure to-day was $n = 2{\cdot}70 \times 10^{19}$. As would be seen, the numbers derived from the kinetic theory in the manner described last week were of the right order but were erratic, and this was inherent in this particular method of estimation. It was interesting to note, as illustrating the change of outlook in fifty years, that Meyer apologised for venturing on a quantitative estimate, and it was thus evident that a belief in the kinetic theory of gases was not, at that time, deep seated.

There was another method, based on the equation of Van der Waals, who to account for the observed departure of gases from Boyle's law, modified the gas equation from the form $PV = RT$ to $\left(P + \frac{a}{V^2}\right)(V - b) = RT$. Van der Waals assumed that there was an attractive force between gas molecules which he represented by $\frac{a}{V^2}$. The term b was introduced to take into account the fact that the molecules of the gas were not mere points, but had a finite size, so that when the gas was highly compressed the actual volume of the molecules became comparable with the total volume of the space occupied. In the case of spherical molecules, it could be shown that b was four times the actual volume of the molecules and was thus equal to $\frac{2}{3}\,n\,\pi\,D^3$. Hence, if b were measured, $n\,D^3$ could be determined.

As shown last week, the mean free path was equal to $\lambda = \frac{0{\cdot}7}{n\,\pi\,D^2}$, and λ could be determined, as then explained, from measurements of the viscosity.

Hence, as we thus knew nD^3 and nD^2, the value of D and N could be found.

This procedure was not always followed as sometimes it was considered preferable to calculate D from a value of n determined independently. Thus Jeans, taking n as $2{\cdot}75 \times 10^{19}$, calculated the following values for half the diameter of the molecule for various gases :—

	$\frac{D}{2}$ from b	D from mean $\frac{D}{2}$ free path
Hydrogen	$1{\cdot}26 \times 10^{-8}$	$1{\cdot}34 \times 10^{-8}$
Helium	0·98	1·11
Nitrogen	1·77	1·90
Air	1·65	1·86
Carbon dioxide ...	1·70	2·28

The figures were all of the same order and ran more or less parallel to each other.

It was convenient in many cases to use, instead of n, which represented the number of molecules of a gas in a cubic centimetre at normal temperature and pressure, another quantity N, which represented the number of molecules in a "gramme molecule" of the substance. The "gramme molecule" was a mass numerically equal to the molecular weight of gas and was thus about 2 grammes for hydrogen, 32 for oxygen, and about 40 for argon, which was a monatomic gas. N was constant for all matter and the present accepted value was $N = 6{\cdot}06 \times 10^{23}$, which was therefore the number of molecules in 32 grammes of oxygen, 40 of argon and so on.

Argon being known to have spherical atoms, was specially well suited for determining N from the b in Van der Waal's equation. Perrin had done this and got the value $N = 6{\cdot}2 \times 10^{23}$, which was a result derived directly from the kinetic theory, and which it would be seen agreed closely with what was now believed to be the true value.

The methods of evaluation so far described were all based on the kinetic theory, which at the time the calculations were made could not be regarded as more than a working hypothesis. Within the last fifteen years, however, there had been an experimental verification of the theory, due to the study of the Brownian movements. These were discovered in 1827 by the naturalist Brown, who, examining under a high-power microscope a liquid in which very minute spores were suspended, noted that these spores were in constant motion. For seventy years this remained practically an isolated observation, and the movement was commonly attributed to eddies in the liquid. About 1880, however, physicists began to suspect that they were due to something much more fundamental. According to the kinetic theory the molecules of gas were in constant motion to and fro, and it was anticipated that the molecules of every liquid would be in corresponding but more restricted motion. If this were so, the Brownian movements would be the inevitable consequence of the molecular agitation. A particle immersed in a gas, for example, would be bombarded by the molecules on all sides, and on the average not more in one direction than another. There were, however, fluctuations in the number of molecules present at any moment in a very small volume of the gas and also fluctuations in their velocities. As a consequence, when the particle was small enough, the existence of these fluctuations caused the momentum it received from the bombardment on one side to be momentarily greater than that received from an opposite side, and the particle was accordingly started into motion through the gas. The distance travelled, before it was brought up, would be greater the smaller the particle and the greater the viscosity of the gas. Exactly the same kind of thing happened when particles were suspended in a liquid, and in a liquid as viscous as glycerine the Brownian movements were sluggish.

Perrin had traced actual paths followed by particles. These were represented in Fig. 2, and it would seem that they were extraordinarily erratic. The path between successive observations was represented in the diagram by a straight line, but this was inexact.

Perrin had made the first really systematic study of these Brownian movements and had arrived at results of great interest and importance. By successive centrifuging he obtained particles of gum arabic and of mastic which were throughout of the same diameter. This diameter was determined by microscopic measurement, by the application of Stokes law to the rate at which they settled through a fluid, and by precipitating them in small groups and weighing these. The particles were thus of known diversity and of known diameter, and a suspension of them in a fluid constituted a kind of artificial gas.

As was well known, the atmosphere was less dense at high levels than lower down. At about a height of 6 kilometers its density was one-half of what it was at sea level. The height at which

Fig. 2.

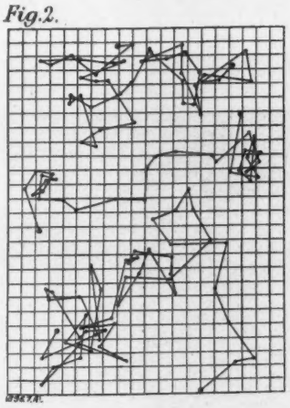


Fig. 3.

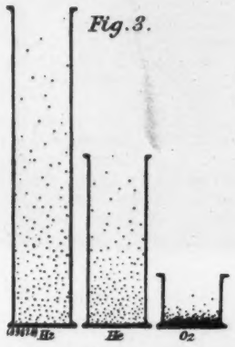
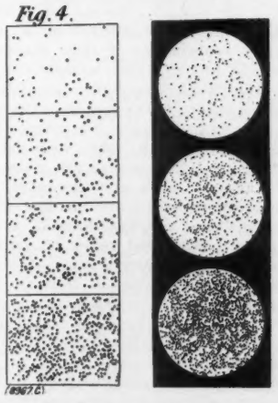


Fig. 4.



half density would be attained depended upon the gas, and Fig. 3 showed this diagrammatically. Thus in an atmosphere of hydrogen half value would be obtained at 16 times the corresponding height for oxygen, and in one of helium at four times the height. The height in short depended upon the molecular weight, and a Brownian particle, considered as a molecule, had a molecular weight running into billions. Hence, considering the suspension of these particles in a liquid, half density would be attained at a level of perhaps $\frac{1}{1000}$ of a millimetre instead of at 6 km., as with air. The density of the particles diminished in geometric proportion with the height. Perrin counted under the microscope the number of particles visible at different levels of his suspensions, and Fig. 4 showed the distribution observed at these different levels.

The pressure of gas was directly proportional to the number of molecules in a cubic centimetre. In the case of any column of gas, the pressure p diminished with the height h according to the geometric law

$$\frac{p}{p_0} = e^{-kgh} = \frac{n}{n_0},$$

where p_0 denoted the pressure of the gas at the bottom, and k was given by the relation

$$k = \frac{N\,m}{R\,T}$$

where N denoted Avogadro's constant (the number of molecules in a gramme molecule) and m the mass of the molecule, whilst T was the absolute temperature and R the gas constant. If, in the measured height h, n became $\frac{n_0}{2}$ then

$$h = \frac{0{\cdot}693\,R\,T}{N\,m\,g}$$

or

$$h \propto \frac{1}{m}$$

If, then, h and m were measured, the value of N could be deduced.

Perrin counted some 13,000 particles which measured $0{\cdot}212\ \mu$ in diameter. The distribution at different levels was as follows :—

h =	5 μ	35 μ	65 μ	95 μ
Ratio of number of particles	100	47	22·6	12
Geometric Progression	100	48	23	11

From these observations he deduced for N the value $N = 6{\cdot}83 \times 10^{23}$. The true value was now held to be $6{\cdot}06 \times 10^{23}$, and in view of the very great difficulty of Perrin's experiments the agreement was surprisingly good. Perrin improved his figure slightly in subsequent observations.

There were other ways of deducing N from the study of the Brownian movements. Thus we might select a particle and follow it from moment to moment. The course followed appeared to be completely confused, but by extending the observations over several days we could make use of statistical laws which, as worked out by Einstein, showed that if x represented the displacement of the particle parallel to the x axis, we should have $\Sigma \frac{x^2}{t}$ equal to a definite constant where t denoted the total time. This constant depended on the size of the particle and on the viscosity of the fluid.

Another interesting result had been established by Perrin. In general, molecules did not merely move to and fro, but they were also set in rotation by the collisions they experienced. By Maxwell's law, the average energy of rotation of the Brownian particles should be equal to the average energy of translation. Perrin found a particle with an inclusion which made it possible to observe its rotation. He thus proved that Maxwell's law was obeyed with sensible accuracy.

More complete experiments on the Brownian movements had since been made by Westgren in Sweden, who found $N = 6{\cdot}0 \times 10^{23}$; by Nordlund, who studied the motion of particles of mercury in water and got $N = 5{\cdot}9 \times 10^{23}$; and, in particular, by Fletcher in Chicago, who employed an oil drop of definite size suspended in rarefied air, and found $N = 6{\cdot}0 \times 10^{23}$. These experiments demonstrated that the kinetic theory was true in detail.

Another method of determining N originated with the late Rayleigh, who showed that the blue of the sky depended upon the number of molecules per cubic centimetre. He first discussed the subject in 1871, and his final results were published in 1899. He showed that the blue was due to the scattering of the sunlight by the molecules of the air. That small particles would scatter light of a blue colour had been shown earlier by some famous experiments of Professor Tyndall. If light passed through a medium containing particles having a diameter smaller than the wave-length, these particles scattered light in all directions. The amount scattered by each was small, but when the particles were multitudinous, the total effect became large.

Rayleigh discussed the matter mathematically, and showed that the proportion scattered was inversely proportional to the fourth power of the

wave-length, and thus violet light would be scattered 16 times as much as red light. He also showed that the light scattered at right angles to the original beam would be completely polarised, and he worked out a formula for the attenuation (due to this scattering) of the light transmitted through different thicknesses of air. He showed that the intensity E_n, the light transmitted through a stratum of air of thickness x, was given by the expression

$$E = E_0 e^{-hx}$$

Here h denoted the attenuation coefficient which he showed was equal to

$$\frac{32 \pi^2 (\mu - 1)^2}{3 n \lambda^4}$$

where μ denoted the refractive index of the air, n the number of molecules in a cubic centimetre, and λ the wave-length of the light. Observations on the rate of attenuation had to be made at mountain observatories in order to avoid effects due to the pollution of the lower strata by dust. Many such observations had been made at Mount Wilson, and Avogadro's constant deduced therefrom. Thus King (1912–14) found $N = 6{\cdot}23 \times 10^{23}$, and Fowle in 1914 got the value $6{\cdot}05 \times 10^{23}$.

THE LEIPZIG FAIR.

(*Concluded from page* 296.)

THE exhibition hall for machine tools is a reinforced concrete building with a steel roof construction of unusual design and with a massive stone front enclosing the entrance hall, the offices, and restaurants. To the British eye the design appears very heavy, an effect which is greatly increased by the many pillars of square cross-section which extend to the roof. Roof trusses built up of nickel-steel sections with very deep webs, only about $\frac{1}{8}$-in. thick, are used, the form of these being clearly shown in the two accompanying illustrations. Although an impression of the great size of this hall is given by these two views, it may serve to make comparison with other exhibition halls if the dimensions are given. In length the machine-tool hall is 600 ft., and in breadth 260 ft. The total sum spent upon its erection was 250,000*l.* and the estimated value of the machines on show is about 6 250,000*l.* The floor space is divided up by two cross-corridors, in addition to those at the ends, and by six longitudinal passages, each bearing the name of a leading machine tool manufacturer. Accommodation for 556 stands is provided on the ground floor, and for a further 166 in the two balconies, which run the whole length of the hall at the sides. Every part of this large space is occupied by machine tools proper, hand tools and accessories being shown in other buildings. Consideration of this extensive display, arranged for an exhibition which lasts but a fortnight, may be commended to British machine-tool exporters.

A lesson may be learned not only from the way in which the stands have been taken up by the German manufacturers, but also from the actual machines which are shown. No one could view the products in this show without feeling that there is going to be very severe competition in the near future in the machine tool markets of the world. At present the policy of the German manufacturers regarding export business seems to be of the nature of a waiting game, for they have not yet obtained clear information on the prices at which machine tools can be sold by other countries. Generally speaking, the prices of to-day are high; at any rate, that was the case at the opening of the Fair. In some other spheres prices were cut after the opening day, and it is highly probable that if the prices originally submitted by the German machine tool makers are not such as to prove attractive, efforts will be made to reduce them to obtain a footing in the markets. Whatever period must elapse before the true position in regard to the machine tool prices of other countries is understood, there can be no doubt whatever that mighty efforts are to be made by "dumping" in the foreign markets once the home demand has been satisfied. With such a prospect in front of them, it is essential that the British firms who participate in the trade of colonial and foreign markets should be warned of what they will have to face in the future. Many of the exhibits—most of them, we might say—are of the type in which simplicity is the keynote of the design, as it seems to be thought that first cost of the products is the vital factor in the consideration of the reconstruction of trade.

The German manufacturers have the advantages of cheap labour and can therefore produce at smaller costs than the British concerns. The export duty is a drawback to the immediate increase of German trade, but, since there is now a Minister of Technics in the Government, the position of the technical industries of Germany will not be allowed to be forgotten and whatever type of assistance is necessary to effect a recovery of trade it may be anticipated immediately the time for its institution is ripe. Once a footing is established in overseas markets and the British concerns are faced with either maintaining their position at a loss or sacrificing the continuance of their share in the trade, it will be brought home to the British engineering public what thorough organisation for selling and far-sighted policy means to the German producer. At such a time everything that is possible should be done to make such reductions in the costs of manufacturing as will make certain the sale of machine tools on a competitive basis. Selling organisations in the overseas markets must be strengthened and propaganda work extended. We have recently witnessed orders for ships going to Holland and to Germany because of considerations of first costs and times of delivery. Sooner or later we are certain to have a similar experience in relation to machine tools, unless efforts are made immediately to prepare for the impending onslaught upon the markets.

In addition to the many machine tools of orthodox design which are shown, there are some of outstanding merit which deserve special reference. Amongst those of imposing dimensions may be mentioned a vertical boring mill, which can work to a diameter of 8,000 mm. or 26 ft. This is the largest of a series of nine models shown by the same organisation, the smallest of which will deal with jobs up to 2 ft. diameter. Of the tools for use in locomotive construction, there are many, and one of these, for grinding crankshafts to form, deserves comment. In this machine the crankshaft is given a solid support within a surrounding ring, on which the grinding wheel is mounted. The drive for this ring, within its casing, is given through a worm and worm wheel from a gear drive on the electric motor. An auxiliary electric motor drives the grinding wheel, and obtains its supply through slip rings on the revolving ring, to which the current is conducted through brushes. Once the crankshaft is set up in position for the treatment of any particular part, the grinding wheel is set in motion and the drive for its supporting ring brought into action. Grinding crankshafts from the rough may be rapidly performed with the machine, and control is possible to any desired limits of precision. Automatic machines in great variety are shown by many of the largest German manufacturers. The heavy shears and punching machines used in shipbuilding are also to be seen, a feature not usually characteristic of exhibitions held in this country. What is claimed to be one of the heaviest electrically-driven shears ever built is exhibited. This is capable of cutting rounds up to 9 in. in diameter from 28-ton to 30-ton steel, and up to $6\frac{1}{2}$ in. in material with a breaking stress in tension of 52 tons per square inch. It is also capable of dealing with squares and slabs of corresponding cross section. The shearing pressure the machine was designed for was 1,500 tons. The machine drive is obtained from an electric motor of 100 h.p. through belting. A separate motor is provided for the holder down or kicking strap, and this is cut out of action as soon as the holder reaches its highest position after the completion of each stroke or when, by its downward movement, the billet or slab is securely gripped.

FIG. 1. THE MACHINERY HALL.

Further machine tools of the small sizes, together with the hand implements used in industrial work, are exhibited in another hall. These are standard articles, made by repetitive processes, and examples of the range of qualities found in every country where they are utilised are to be seen. In some cases the prices are lower than is the case in Great Britain, but usually they are the same or even higher. The great electrical firms of Germany have prepared exhibits of their products that bear ample testimony to the good quality of their design and manufacture, and the immense variety of their products. There is no evidence in this section of the Technical Fair of any slackening off in the efforts of the manufacturers to keep abreast of every modern development. Compensated polyphase motors without slip rings, in sizes up to about 7 h.p., are shown on some of the stands. These, in the smaller sizes, have short-circuited rotors, but starting devices built into the rotors are used in the larger units. In these the features of simplicity and safety of operation characteristic of the normal polyphase motor have been largely retained, and an endeavour has been made to keep the price

down to as near that of the uncompensated type as possible.

Of motive-power engines there is an excellent display of every type—steam turbines, steam engines, and gas and oil engines. One tendency that is shown by the exhibits on many of the stands is the development of the small Diesel engine. Complete units of as low as 5 h.p. are available for inspection, or are running. From this size up to the large units used in ship-propulsion, engines are shown in great variety and designed for driving electric generators, pumps, motor-boats, and workshop shafting. Brown coal and lignites are common in Germany, and one hall is devoted to the display

FIG. 2. MAIN AVENUE; MACHINERY HALL.

of plant used in their mining and their use. Here are to be seen drying plants, briquetting machinery, and furnace constructions suited to the burning of these inferior fuels under boilers.

With the loss of Alsace, Germany forfeited her principal works for the manufacture of textile machinery. To make the country as independent as possible of foreign suppliers, many of the large engineering concerns have now undertaken manufacture in this highly specialised work. The machines exhibited—mostly ring-spinning frames and doubling or twisting machines, drawing and fly frames—bear testimony to successful work in a new sphere, specialists having been engaged to deal with this new line of work. A new carding machine in which all the toothed wheels are milled to form and in which the balancing of the rollers has received careful study, is a conspicuous exhibit. In this machine the top is made to cover as closely as possible in order to reduce the formation of waste to a minimum.

The iron and steel industries are well represented, not only by exhibits of the raw materials of other industries which they manufacture, but also by examples of products made from them. In this section there are many very good examples of forgings and stampings. For the chemical industries there are shown mixing plants, filters, grinding plants, and many of the metals which have been developed to resist the actions of heat and acids. Outside the many halls there are exhibits of many types of conveyor systems for coal, ash, and for the discharge and loading of wagons. In association with these there are all types of tipping wagons and grabs.

From what has been said of this year's Leipzig Fair, it will be appreciated that it still retains its position, and is long likely to do so, as the most important continental annual exhibition. The quality of the display that the German manufacturers make there is worthy of appreciation, and it seems regrettable that some, at any rate, of the largest and most representative of our own manufacturers do not endeavour to obtain business through this useful means of coming into contact with buyers, who normally look to German producers for their plant. There can be no doubt that British machinery would earn an enhanced reputation when shown in contrast with the products of the greatest manufacturing country on the Continent, and particularly where substantial construction is sought by the user, the decisions would almost certainly favour the machines of British origin. The Leipzig Fair, though of short duration, does seem to attact the right type of people, and as there are no side shows to appeal solely to the amusement-seeker, it may be taken that everybody who does go has some business interest in doing so.

THE INSTITUTE OF METALS.

THE seventeenth annual general meeting of the Institute of Metals was opened last Wednesday morning, the 11th inst., in the Hall of the Institution of Mechanical Engineers, Professor Turner, the president, occupying the chair. The meeting continued yesterday.

REPORT OF THE COUNCIL.

The annual report for the year ending December 31, 1924, referred to the steadily-increasing support which the Institute was receiving from manufacturers, users and scientific workers. At the date named the membership was 1,571. Mr. A. E. Seaton had been elected a Fellow of the Institute, as a mark of the Council's high appreciation of his services as Hon. Treasurer over a long period of years. For some time past it had been realised that the Institute needed more house room; a committee had been appointed to consider the question of securing additional office accommodation, and a House Fund had been started to which members were invited to contribute.

CORROSION RESEARCH.

The work of the Corrosion Research Committee had been reorganised during the year. The change was made as from April 1, 1924, on which date Dr. Bengough and his collaborators left the service of the Institute and entered that of the Department of Scientific and Industrial Research. Mr. R. May, joint author with Dr. Bengough of the Seventh Corrosion Report, remained in the service of the Institute, and was carrying on technical work on the prevention of condenser tube corrosion. The work of the Aluminium Corrosion Sub-Committee had been wound up, and a final report presented to the Department of Scientific and Industrial Research, but pending the clearing up of the position as regards patents no publication of the results had been permitted.

REPORT OF THE HON. TREASURER.

This, the first report of Mr. J. Fry, as Hon. Treasurer, stated that for the financial year ended June 30, 1924, the deficit was only 6*l.* 7*s.* 4*d.*, as compared with a deficit the previous year of 580*l.* 16*s.* 7*d.* The income for the year was 5,761*l.* 3*s.* 6*d.*, and the expenditure 5,767*l.* 10*s.* 10*d.* The largest amount of expenditure was, as usual, that for the Journal.

AUTUMN MEETING.

In the course of the introductory proceedings, it was announced that the autumn meeting would take place in Glasgow from September 1 to 4.

GRAIN-SIZE AND HARDNESS.

The first paper taken, contributed by Mr. H. T. Angus and Mr. P. F. Summers, had for its title "The Effect of Grain-Size upon Hardness and Annealing Temperature." It was read in abstract by Mr. Angus.

It showed that the grain-size of a metal just before rolling considerably affected its hardness, when annealed after rolling at temperatures up to the re-crystallisation temperature. It was well known that many heavily-worked metals increased in hardness on annealing for a short time at relatively low temperatures, and this property depended, among other conditions, upon the grain-size existing at the time of rolling. A coarse grain-size increased the rise in hardness and the range of temperature over which it extended, whereas with a fine grain-size, softening might commence at much lower temperatures. This effect was noted in both pure copper and in bronze containing 4·5 per cent. of tin. The re-crystallisation temperature of copper was higher in the coarse-grained metal than in the fine-grained, in which almost complete softening occurred before signs of re-crystallisation appeared, whilst in the coarse-grained copper the same degree of softening was only reached when complete re-crystallisation occurred. The relation between grain-size and hardness for copper and bronze showed that as the grain-size increased after re-crystallisation, the hardness decreased correspondingly.

The discussion was opened by Professor F. C. Thompson, who thought that the authors' conclusions would have been greatly strengthened had they been accompanied by microsections illustrating them. In their curves for copper, 500 to 800 grains per square millimetre before rolling, in which increased hardness was found after softening had been completed, this was not the first time this had been shown to be the case, since nickel-silver evidenced the same peculiarity very clearly. There was, therefore, good evidence to substantiate the authors' statements in this direction. The authors had said, with reference to copper, that at a temperature of 500 deg. C. fairly complete softening had occurred, although recrystallisation was not quite complete until 600 deg., when a slight increase in hardness was found, possibly due to the decrease in grain-size; this, according to Professor Thompson, was not quite clear and required further explanation. In their curves showing the relation between the amount of grain boundary and hardness of bronze and brass, he suggested they should have drawn them per unit length instead of on the square root per unit area, since crystallisation was the same in both instances; the curves might thus have been clearer.

Dr. Rosenhain expressed the view that caution had to be exercised in regard to several of the authors' conclusions. For example, it was not easy to be sure when recrystallisation had occurred. The past history of the metal had also a very great effect upon the subsequent treatments. Dr. Rosenhain mentioned the X-ray examination of metals, and stated that in the case of silver foil, for example,

X-rays revealed a typical cold-work effect. The paper showed one direction in which X-ray work could be extended, namely, the behaviour of crystals during re-crystallisation.

Dr. H. W. Brownsdon referred to the Brinell hardness curves of the authors' which may have been obtained on the basis of a ratio different from that of other workers; this might have had a great influence upon their conclusions as against those of such other workers.

Miss Elam thought that some only of the hardness could be removed before recrystallisation took place, and had used X-ray examination to make sure of the point. She also questioned the abrupt change in the authors' curves illustrating the effect of grain-size upon the hardness of copper, bronze and cartridge-brass, and added that Brinell tests on single crystals had no real value.

Colonel Belaiew agreed with Dr. Rosenhain as to the importance of the previous history of the metal. The influence of the grain-size was of great importance in some circumstances, and when speaking of grain-size one had to be sure that one was not dealing with an aggregate. The size of the balls of course also came in.

Dr. Hatfield said that in his experience it was not possible to obtain complete softening until one arrived at complete re-crystallisation.

Mr. Angus, in the course of his reply, and with reference to microsections, said that the authors had not seen the importance of the results they had obtained until afterwards when they could not get the microsections. In reply to Professor Thompson's demand for an explanation of a passage in the paper, the first hardness number was taken before recrystallisation commenced, when a softening effect was found; there was then a finer grain and hardness increased. Recrystallisation had occurred. He further said that they had started on homogeneous alloys in which no component was harder than the other. They were continuing with the cupro-nickel series. With reference to the statement to the effect that complete softening did not occur without recrystallisation, they (the authors) had only said they did not observe it, but did not say it did not occur.

ALUMINIUM ALLOY CASTINGS.

The second paper had for its title "A Method of Improving the Properties of Aluminium Castings." The author, Mr. S. L. Archbutt, of the National Physical Laboratory, read it in abstract. We reproduce it in an abridged form on page 336.

The discussion was opened by Dr. R. Seligman, who said this was essentially a practical paper of importance, equal in practical interest as was the first one from a theoretical standpoint. It was of outstanding value to all concerned in the manufacture and use of aluminium. The unsoundness phenomena dealt with were by no means uncommon, and they occurred in the form shown by the author, when the pieces were cast in sand, whilst many of them were disposed of when they were cast in metal moulds. Their effects were more widespread than was frequently realised. Sheet metal, for example, although obtained of high quality, was sometimes very difficult to weld, and he felt sure the explanation would be found traceable to the care, or lack of care, given to the casting. Notched bars giving a perfect analysis could be found to break easily; those notched bars carried their undesirable properties from the casting. Sheet aluminium frequently showed corrosion effects which could not be explained otherwise than arising from occluded gases. He was, therefore, glad the author had shown a method of overcoming the trouble. Foundrymen, however, might not find that method a practical one in every-day practice, and the National Physical Laboratory might give more details on the practical way of carrying out the method. The author had said that the bulk of the occluded gas was eliminated during solidification, but some must be eliminated before solidification commenced. What was the gas liberated? Was it due to the "original sin" pre-existent in the metal, or to the method of re-melting? He (the speaker) suggested that the "original sinners" were the first makers of the metal, and if the nature of the gas was known an important point would be ascertained. The makers of the metal were, no doubt, the persons to deal with. But some statements of the author would seem to cast blame upon those responsible for the further treatment of the metal, except in the case of the metal which came from Norway and was improved by successive treatments.

Captain J. Cartland asked whether if the metal were put under a reduced pressure, improvement would not follow by a removal of the gases.

Colonel Belaiew said he had on several occasions brought to the notice of producers results obtained at the National Physical Laboratory; their reply was to the effect that difficulty was encountered in obtaining them in every-day factory work. The factories should be shown how to work and how to organise the inert gas method.

Dr. Gwyer said the main gas present in aluminium was hydrogen so far as was known, and the hydrogen might have gone in the solid solution. The working under reduced pressure was a good method to follow, and a large amount of gas was got out from the metal before reaching a vacuum.

Dr. Rosenhain said the method dealt with in the paper was an easy one to carry out, and its cost was low. The metal could be spoilt by re-melting if it were exposed unduly to the furnace gases; it might become saturated with gas, and the gas taken up was hydrogen. It was possible to "ingot" the metal in the shape of the crucible, when re-melting would do very little harm. Heating *in vacuo* was sound in theory, and if time allowed it worked well. Molten aluminium after a week still gave off gas; the rate of gas escape was very slow after the larger initial quantity had been removed, and in the present case it was not the larger initial quantity which so much mattered. The blowing through of nitrogen gas was very simple. The method advocated was susceptible of application to many metals and alloys in different ways to suit the different conditions.

THE ANNUAL DINNER.

The Annual Dinner of the Institute was held at the Trocadero Restaurant on Wednesday evening, the President, Professor Turner, being in the Chair. The Institute of Metals having a number of lady members, ladies are naturally admitted to the dinner, which gives the affair the air of a somewhat more social function that is usual with some of the older technical institutions. The toast of "The Institute and the Chairman" was proposed by the Right Hon. Neville Chamberlain, who disclosed the fact that both Mr. Baldwin and himself were old pupils of Professor Turner. "Kindred Societies" was proposed by Dr. Rosenhain, who paid a graceful tribute to the Institution of Mechanical Engineers. Mr. Patchell, in reply, made an eloquent plea for co-operation not only between capital and labour, but also between the various technical institutions.

(To be continued.)

NOTES.

USES OF PETROLEUM.

RETIRING last Tuesday, after two noteworthy years of office, from the presidency of the Institution of Petroleum Technologists, Mr. Herbert Barringer covered in his presidential address the subject of "General Uses of Petroleum, especially in reference to the Production of Power" in so comprehensive a manner that his successor in the chair, Sir Thomas Holland, spoke of the address as a work of reference on the engineering aspects of the utilisation of oil. From this standpoint, Mr. Barringer briefly reviewed the uses of petroleum as a lighting and cleaning agent in the service of hygiene, with special regard to the extirpation of malaria, as raw material for explosives, for road making and for lubrication, and then passed to his main subject, dwelling chiefly on the use of oil on board ship. For steam-raising at sea he considered the pressure system best suited, the oil being preheated to 250 deg. F. and more, and pumped at pressures of 50 to 99 lb. per square inch. At the close of 1924, the fuel consumption on vessels was 17,154,000 tons per annum, against 1,310,000 tons in 1914. In the development of marine Diesel engines, Russia, and the firm of Nobel, had had a large share; Nobels had also built the first four-cycle reversible marine engine in 1907. Last year, 500,000 tons of shipping had been fitted with internal-combustion engines, bringing the total so equipped up to nearly 2,000,000 tons. After mentioning the later double-acting four-cycle engine developments, Mr. Barringer gave test sheets of engines of Nobel, Armstrong-Sulzer (noteworthy for their scavenging arrangements), Richardsons-Beardmore-Tosi (with semi-rotary director valve), and other engines, and referred also to the Scott-Still engine. The percentages of marine-propelling machinery constructed in the form of reciprocating engines, steam turbines and motors, he said, had been 70, 28, and 2 in 1918-19, and 69·8, 11·4, and 18·8 in 1923-24. For moderate powers, the motor would continue to make progress, but for high powers steam turbines would alone be used. Lubrication, motor fuel and detonation were other subjects which Mr. Barringer discussed. The direction of advance, he thought, would lie in the use of higher compression, the efficient application of weak mixtures and possibly in the improvement of fuels.

THE LOSS OF NATIONAL SKILL.

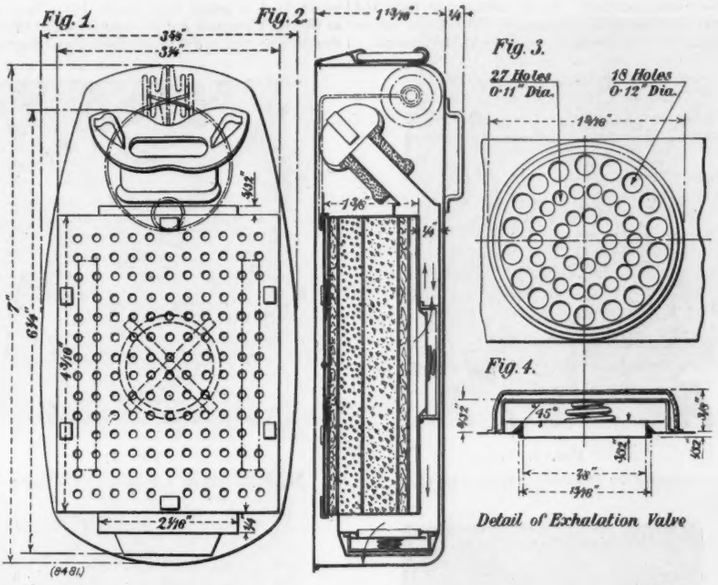
In responding to the toast of "His Majesty's Ministers," proposed by Sir Alfred Herbert at the Annual Dinner given by the Machine-Tool Trades Association on Wednesday, The Right Hon. L. S. Amery, Secretary of State for the Colonies, gave a brief survey of the industrial position of this country. He declared that the true capital of the nation was the skill of the workers. Due to conditions within the last few years, a grave deterioration in that skill had taken place, and this was a much heavier loss than that sustained in terms of money. Recently an order for five oil-engined ships had gone from this country to Germany at a time when experience in constructing this type of craft was most valuable for future requirements. That experience was being capitalised in Germany. What was still worse, however, was that young lads were taking up work in sheltered industries instead of being sent to learn the ordinary skilled trades owing to the low rates of wages which could be earned at the latter work. Our loss, too, had been great through tradesmen emigrating to the United States. When the demand for skilled workers came we should find ourselves handicapped in the industrial contest. There existed urgent need for greater mobility of labour to ensure an adequate supply of men being available for each occupation as the need arose. Mr. Stanley Machin, in responding to the toast of "Our Guests," emphasised the necessity of relieving industry from some part of the burden of taxation. Earlier in the day, the Fourteenth Annual General Meeting of the Machine Tool Trades Association was held under the chairmanship of Sir Alfred Herbert. In his introductory remarks, Sir Alfred stated that the past year had been an active period for the Association. A catalogue had been published in the English, French and Spanish languages, and had been accorded a favourable reception. The chief event, however, had been the holding of the Third Machine Tool and Engineering Exhibition at Olympia, London. By a vote of the members, it was decided to hold the next exhibition at Olympia in 1928.

PERSONAL.—It is announced that John Thompson Water Tube Boilers, Limited, of Imperial House, Kingsway, London, W.C.2, have appointed, as representative for Scotland, Mr. James Ritchie, who will conduct business from his office at 50, Wellington-street, Glasgow.—Mr. John T. Callaghan, of 46, Grosvenor-chambers, Deansgate, Manchester, has been appointed representative for the counties of Lancashire and Cheshire for Sheffield Steel Products, Limited, of Templeborough, Sheffield.

RAILWAY CONSTRUCTION REGULATIONS.—The requirements respecting the opening of railways, which were last revised by the Board of Trade in the year 1914, have now been revised and amplified by the Ministry of Transport, and have been published under the title "Requirements for Passenger Lines and Recommendations for Goods Lines of the Ministry of Transport in Regard to Railway Construction and Operation." Copies may be obtained from any of the branches of His Majesty's Stationery Office (price 3s.).

"M.S.A." CARBON MONOXIDE SELF-RESCUE APPARATUS.

THE MINE SAFETY APPLIANCES COMPANY, PITTSBURG, PA., U.S.A.



"M.S.A." CARBON MONOXIDE SELF-RESCUE APPARATUS.

IN our issue of April 18, 1924, we gave a brief description of the "M.S.A." self-rescuer, which is manufactured by the Mine Safety Appliance Company, of Pittsburgh, Pa. The apparatus is intended purely as an emergency appliance to enable miners to escape in cases where they are caught in an atmosphere charged with carbon monoxide gas. Such atmospheres frequently result from explosions in mines and may also occur in other circumstances, such as in the defective operation of blast furnaces.

We are now in a position to describe this apparatus in more detail, and illustrate it in Figs. 1 to 4 herewith. From the general arrangement, Fig. 1, it will be seen that the appliance consists of a small canister with a mouthpiece directly attached. The wearer breathes through the latter, drawing the contaminated air through the purifying reagents in the canister, and ejecting the exhausted air from his lungs through an exhalation valve mounted below the canister. Until actually required for use, the apparatus is enclosed in an hermetically-sealed brass case, which can be conveniently carried in the coat pocket or attached to a belt by the loop provided. The contents of the canister are thus protected from deterioration due to contact with air, and, when required, the cover, which is seen on the left in Fig. 2, can be ripped off by hand, a finger ring held on the top of the case by means of a soft metal clip being provided for this purpose. On ripping off the cover the apparatus is ready for use, the mouthpiece being gripped between the teeth, and the nostrils closed by means of the pinch-clips seen dotted in Figs. 1 and 2. Inside the main case is the rectangular box or canister shown, containing a number of layers of protective materials separated from each other by perforated metal sheets. The front of the canister is pierced with 148 holes, $\frac{1}{4}$-in. diameter, and the air drawn in through these holes passes successively through layers of absorbent cotton, granular fused calcium chloride, "hopcalite" (granular manganese dioxide), and a second layer of absorbent cotton, after which it passes through a check valve into a passage communicating with the mouth-piece. The object of the first layer of cotton wool is to remove any smoke present, the calcium chloride absorbs water vapour, which, if allowed to remain, would destroy the efficiency of the hopcalite. The latter acts as a catalyst, causing any carbon monoxide to unite with the oxygen present in the air, and thus produce the relatively harmless carbon dioxide. The check valve consists of a mica disc held on a metal seating by means of the light spring shown. The exhalation from the lungs passes down the same passageway and emerges into the atmosphere through an exhalation valve, which is seen at the bottom of Fig. 2. Of this valve enlarged views are given in Figs. 3 and 4. It will be appreciated that the entire value of the apparatus depends on the tightness of this valve, as otherwise gas charged with carbon monoxide will pass directly into the lungs of the wearer of the self-rescuer. It has been found that the most satisfactory form of valve consists of a spring-loaded mica disc resting on a 10 per cent. nickel-silver seat carefully ground to a knife edge. A possible cause of failure of the apparatus lies in the fact that the exhalation from the lungs is normally saturated with moisture, and the latter content is increased when wearing the self-rescuer due to a tendency to discharge saliva. Such moisture may pass through the inhale valve by capillarity and effect the hopcalite, and for this reason the self-rescuer is given a nominal life of one half-hour. A number of tests carried out by the American Bureau of Mines prove that this period leaves a large factor of safety, four men wearing the apparatus having walked about for a period of 70 minutes in an atmosphere containing 1 per cent. of carbon monoxide without ill-effects.

THE BRITISH CAST-IRON RESEARCH ASSOCIATION.—The January issue of the quarterly bulletin of the British Cast-Iron Research Association contains a report of the annual general meeting of the Association held in November last, and gives an account of the recent activities of the council and committees. Notes on the use of scrap in iron and steel manufacture, by Mr. J. E. Fletcher, and on the influence of nickel and chromium upon grey and malleable cast-iron, by Dr. L. Northcott, are published, and a list of recent additions to the Association's library is given. A particularly useful feature of the bulletin is a section giving brief abstracts of articles published in British and foreign technical journals relating to iron production, foundry practice, physical and chemical properties of iron, testing, refractories, and other cognate matters. The registered offices of the Association are at Central House, New-street, Birmingham.

AUTOMATIC POSITION INDICATOR FOR TRAMCARS.—At the present time some 150 cars on the Metropolitan Electric Tramway system are being equipped with a device by means of which passengers may see at a glance their exact position at any time on the route along which they are travelling. The arrangement consists of an oblong wooden case, 6 ft. in length, to which a glass front is fitted, together with a graduated route chart and two rollers, the latter driven by a flexible shaft positively geared to an axle of the tram. The spools are mounted inside the box, one at each end. The chart has printed upon it the various stations on the route, and as it winds from one roller on to the other the stations in turn are made to pass a fixed red pointer on the dial of the indicator. For each mile the car travels the chart moves 6 ft., so that the names of points half a mile ahead and behind the passenger at any time may be noticed. The apparatus is purely mechanical in action, and is the outcome of long continued efforts to find a means of showing strangers and other travellers their position at night time and in case of fog, &c. The proprietors of the automatic route guide are Auto Guides, Limited, of Carlton House, Regent-street, London, S.W.1.

TESTS OF COMMERCIAL COPPER ROD.*

Comparative Tests on Some Varieties of Commercial Copper Rod.

By T. G. BAMFORD, M.Sc.

THE primary object of the present research was to compare the properties of certain distinctive varieties of commercial copper, with a view to ascertaining their relative durability under conditions which they would meet in service, particularly as constructional parts of locomotive fireboxes. Three deoxidised and two "tough-pitch" copper rods were tested. Of the former, the first contained 0·31 per cent., the second 0·53 per cent. of arsenic, while the third contained 1·5 per cent. of nickel and but a trace only of arsenic. Of the "tough-pitch" copper one contained a trace of arsenic, while the other contained 0·45 per cent. of this element. Table I shows their analyses.

TABLE I.—*Analyses of the Copper Rods Used in the Research.*

Variety of Copper Tested.	Lot.	Arsenic. Per cent.	Oxygen. Per cent.	Nickel. Per cent.	Phosphorus. Per cent.	Iron. Per cent.	Silicon. Per cent.
Low arsenical deoxidised	1	0·310	0·014	nil	0·079	trace	nil
High arsenical deoxidised	2	0·530	0·013	nil	0·196	nil	0·004
Nickel-copper	3	0·052	0·011	1·52	0·116	nil	nil
Tough-pitch, non-arsenical	4	0·052	0·084	nil	nil	0·026	0·002
Tough-pitch, arsenical	5	0·453	0·098	nil	nil	trace	nil

Tin, lead and silver, antimony and bismuth, were absent in all cases.

The metal was all supplied by Messrs. Muntz's Metal Co., Limited, in the form of $\frac{1}{2}$ in. diameter soft copper rod. Lots 1, 2 and 3 were cast from electro-ingot metal melted under charcoal, deoxidised by additions of yellow phosphorus, poured into cast-iron moulds of 6 in. cross-section, reheated to bright red and extruded to $\frac{5}{8}$ in. diameter. They were then drawn to $\frac{1}{2}$ in. diameter cold and annealed at 600 deg. C. for 20 minutes. The arsenic was added as grey metallic arsenic, and the nickel was added as cupro-nickel. Lots 4 and 5 were cast from fire-refined "tough-pitch" copper also in 6-in. moulds, were rolled down hot in bolt rolls, drawn in one hole for the purpose of sizing them up accurately, and finally annealed as above.

Sir Henry Fowler, in the 1923 Autumn Lecture to the Institute of Metals, enunciated the chief causes of failure of copper when it is used in engineering. These were as follows:—(1) *cracking*, as the result of repeated stress; (2) *wear*, probably due to erosion and oxidation; and (3) *gassing*, due to the heating of the metal to temperatures as high as 750 deg. C. in a reducing atmosphere. He further stated that copper containing as little as 0·015 per cent. of oxygen was ruined by treatment in reducing gases at 650 deg. C.

Lorenz stated that the fracture of locomotive stay-bolts is caused by fatigue, by bending resulting from unequal expansion. An anonymous writer found that copper tube plates of locomotive boilers often develop cracks after a very short life. These are said to be due to (1) expansion of the parts, and (2) excess pressure on the metal caused by the use of tube expanders during repairs. It appears, then, that the qualities particularly desirable in the metal are ability to withstand repeated stresses and resistance to fatigue, freedom from liability to gassing, a minimum susceptibility to oxidation, and also a hardness and strength which will enable the metal to stand up against abrasion and to resist pressure.

In addition to regular tensile tests and hardness tests, it has therefore been thought desirable to carry out Wöhler tests, Izod tests, and Stanton tests.

The first part of the present research consisted of an exhaustive series of mechanical tests carried out upon the material as received from the works. It was also desired to submit the bars to an entirely similar set of tests after severe "gassing" treatment. Preliminary experiments were carried out with a view to deciding which of the reducing gases was most harmful. A sample of pure unworked copper containing a very high percentage of oxygen (0·5 per cent.) was submitted respectively to the action of pure dry carbon monoxide, hydrogen, methane, and sulphur dioxide for one hour at various temperatures. Hydrogen visibly cracked the metal at 750 deg. C. Carbon monoxide at 900 deg. C. penetrated in its action only to a depth of about 1 mm. from the surface, removing the oxide from this outer layer, confusing the structure, and causing therein the formation of very fine microscopic cracks. Sulphur dioxide at 900 deg. C. produced no effect discernible

* Paper read before the Institute of Metals, London, on Wednesday, March 11, 1925. Abridged.

under the microscope, but if a trace of air were admitted with the dioxide, considerable quantities of trioxide were formed and the metal developed a twinned structure throughout. Apparently some internal stress is brought to bear which is insufficient to crack the metal, but is sufficient to alter its structure. Marsh-gas at 900 deg. C. had no apparent effect upon the metal beyond the deposition of a small quantity of soot upon the surface.

It is clear that hydrogen is most rapid in its gassing effect, and metal able to withstand this gas at high temperatures will also resist successfully the influence of other reducing gases. Portions cut from each set of bars were, therefore, treated in hydrogen in an electric furnace maintained at 900 deg. C. for half an hour. These specimens were submitted to the same series of mechanical tests already outlined.

With regard to the influence of heating in air at high temperatures, since the metal has already been submitted to these conditions in its process of manufacture it is not possible that a further treatment could injure the metal radically. The effects produced by heating the metal in air can, in fact, only be those generally incidental to more complete annealing and to oxidation of the metal. Samples of each lot heated in air were, therefore, investigated only, with a view to determining the nature and extent of oxidation, the influence upon the hardness of the metal, and the extent of recrystallisation, and modification of structure. The structures of the lots, as received, are shown in Figs. 1 to 5. Fig. 6 shows the structure of the nickel-copper after treatment in hydrogen. Marked grain-growth has taken place in this alloy, but signs of injury are absent. Lots 1 and 2 show little change in structure after the treatment. Lots 4 and 5 are, however, pitted with holes and cracks easily discernible after light etching. Fig. 9 illustrates this point.

Brinell Hardness Tests.—The results of the hardness tests are shown in Table II. These were carried out, using a 2-mm. ball and direct load of 20 kg., and thus

TABLE II.—*Brinell Hardness Numbers (2 Mm. Ball 20 Kg. Load) of the Lots as Received, After Drastic Heat-Treatment and also After Fatigue Fracture both With and Without Previous "Gassing" Treatment.*

Lot.	As Received.	After Treatment (in Air) for 10 hours at 750 deg. C.	After Treatment in Hydrogen for 0·5 hour at 900 deg. C.	Brinell Numbers taken near the Breaking Section after Fatigue Fracture in the Amsler Machine.	Brinell Numbers taken near the Breaking Section after Treatment in Hydrogen for for 0·5 hour at 900 deg. C. and Subsequent Fracture in the Amsler Machine.
1	53·0	38·1	50·5	66·0	65·0
2	53·5	41·9	46·2	69·8	68·3
3	53·5	68·5	68·0	69·2	86·2
4	39·8	36·4	41·9	62·5	53·8
5	45·9	38·7	40·3	63·5	56·0

correspond to value which would be obtained with the 10-mm. ball and 500-kg. load. Duplicate results obtained near the outside and centre of the metal were taken in all cases, and the average values are given in the table. In no case was any material difference in hardness found in different parts of the sample.

It will be noticed that in the fully annealed specimen there is no great difference in hardness between Lots 1, 2, 4, and 5, although, as received, all the

TABLE III.—*Tensile Tests Carried Out upon 8-In. Pieces of the Rods as Received and after Treatment in Hydrogen.*

Sample.	Treatment before Testing.	Maximum Stress. Tons per Sq. In.	Elongation. Per cent. on 2 in.	Contraction of Area. Per cent.
1	As received	15·8	67	83
	After ½ hour in hydrogen at 900 deg. C. ..	15·2	63	75
2	As received	15·8	66	81
	After ½ hour in hydrogen at 900 deg. C. ..	15·4	60	78
3	As received	17·0	60	79
	After ½ hour in hydrogen at 900 deg. C. ..	19·8	40	62
4	As received	13·8	53	67
	After ½ hour in hydrogen at 900 deg. C. ..	8·9	10	7
5	As received	14·7	65	67
	After ½ hour in hydrogen at 900 deg. C. ..	9·0	11	6

deoxidised specimens were harder than the "tough-pitch" varieties. All the types attain a similar order of hardness after undergoing fatigue fracture. The striking feature of the tests is the marked increase of hardness developed in the nickel-copper after heating either in hydrogen or air, and its further development of greater hardness than is the case with all the others after treatment in hydrogen and subsequent fracture by fatigue. This is the case, although treatment at 900 deg. C. in hydrogen was followed by furnace cooling.

Tensile Tests.—The results of the tensile tests are given in Table III. These tests were carried out upon the unturned rods. In all subsequent tests the necessary machining was invariably carried out before submitting the specimens to any gassing treatment.

FIG. 1.
Deoxidised Low Arsenical Copper as Received.

FIG. 2.
Deoxidised High Arsenical Copper as Received.

FIG. 3.
Deoxidised Nickel-Copper as Received.

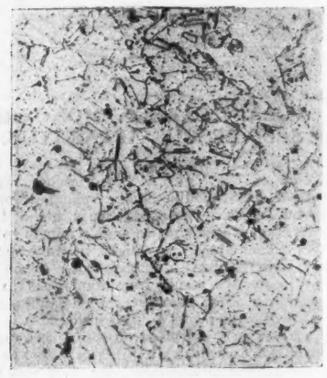


FIG. 4.
"Tough-Pitch" Non-Arsenical Copper as Received.

FIG. 5.
"Tough-Pitch" Arsenical Copper as Received.

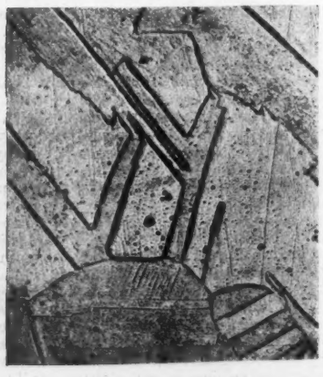


FIG. 6.
Nickel-Copper after Treatment in Hydrogen at 900 deg. C. for Half Hour.

(ALL SPECIMENS ETCHED BY POLISH ATTACK WITH AMMONIA AND HYDROGEN PEROXIDE. × 250.)

Duplicate and sometimes triplicate results were obtained. Lots 1, 2, and 3 showed remarkably little deterioration of properties, while Lots 4 and 5 were quite ruined. The nickel-copper showed marked increase in the tensile figure coupled with quite high ductility.

Alternating Stress Tests.—The alternating stress tests were carried out in Amsler's rotary bending testing machine, a photograph of which is shown in Fig. 12.

The test bars are gripped in the middle in a central support on plummer blocks, and the load, which is a direct one, acts at about 4¼ in. from the section of fracture. The amount of material in each lot limited the number of tests possible. An attempt was made to apply to each lot such a load as would cause fracture only after a great many revolutions (over four million), and this was done in all cases except Lot 4, for which such a small load would have been necessary as to throw the test out of comparison with the others. Practically the same loads were then applied to the material treated in hydrogen, except in the case of Lot 5, which was so brittle after treatment that it broke after revolving for less than two minutes with a load of 0·58 ton per square inch, less than that which it withstood before treatment for 3½ days, and again after revolving for only 34 minutes with a load of 1·94 ton, less than that under which it was able to stand up for 5 hours before gassing. The results are shown in Table IV.

The order of resistance of the material as received to the rotary bending tests was Lot 3, Lot 1, Lot 2,

Lot 5, and Lot 4, in descending order. After treatment Lot 4 and Lot 5 were completely spoiled. Lot 3 still had the highest fatigue resistance. Lot 2 deteriorated very little. Lot 1 suffered somewhat seriously, but still had quite good properties.

FIG. 7.
"Tough-Pitch" Non-Arsenical Copper after Heating in Air for Ten Hours at 750 deg. C. × 250.

FIG. 8.
Same as Fig. 7. × 500.

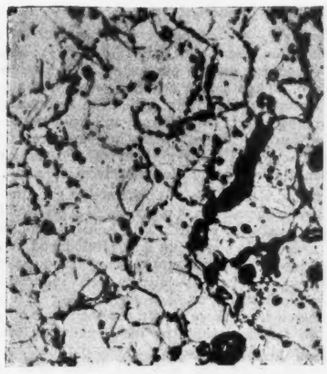


FIG. 9.
"Tough-Pitch" Arsenical Copper after Heating in Hydrogen for Half Hour at 900 deg. C.

FIG. 10.
"Tough-Pitch" Arsenical Copper after Heating in Air for Ten Hours at 750 deg. C., showing Large Grains. × 50.

(FIGS. 7 TO 10 ETCHED BY POLISH ATTACK WITH AMMONIA AND HYDROGEN PEROXIDE.)

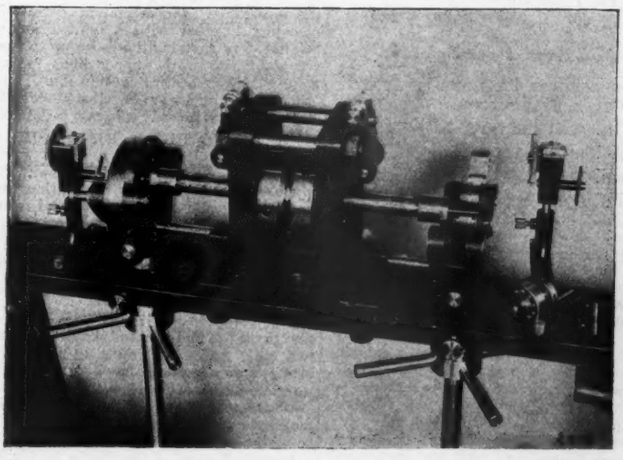


FIG. 12.
View of Amsler Rotary Bending Testing Machine.

Izod Tests.—The Izod tests were carried out in an Avery 120 ft.-lb. machine upon standard rectangular test bars. The results are shown in Table V.

Lot 5 was ruined, and Lot 4 rendered extremely weak and brittle by treatment. Lots 1, 2, and 3 were quite tough after treatment, but Lot 3 absorbed the most energy in bending.

Stanton Tests.—These were carried out upon standard test-pieces. Impact blows of 0·229 ft.-lb. applied at the rate of 130 blows per minute.

The Stanton test is one which should not be interpreted too strictly, as soft copper is not well suited to such a test. The results indicate, however, that the "tough-pitch" varieties are ruined by the gassing treatment, and in all other cases apparently a higher Stanton figure is obtained after than before treatment in hydrogen, but both before and after treatment Lot 3 showed inferiority to Lots 1 and 2. (See Table VI, page 334.)

Scaling Experiments.—The scaling experiments are detailed in Table VII.

The scale which formed in Lots 1, 2, and 3 peeled very easily, leaving a clean surface. The major part of the scale formed on the "tough-pitch" arsenical copper was easily removed, but small specks adhered very firmly. The scale formed on Lot 4 was very adherent, and, in fact, could not be removed by quenching, tapping, and scraping. This probably accounts for the fact that the amount detachable in experiment B (Table VII) is less with Lot 4 than in the case of Lots 1 and 2. Experiment C shows that the actual amount of oxygen taken up by the copper is practically the same in the case of Lots 1, 2, 4, and 5. In all cases it was least with nickel-copper.

Microscopic examination of the specimen showed that expected grain growth had taken place, but the deoxidised copper and nickel-copper showed no evidence of oxide penetration.

The "tough-pitch" annealed, non-arsenical copper, however, unetched and also etched, revealed distinctly large grains of oxide, and in rather greater quantities than before annealing. The same condition in slighter degree was evident in the case of the arsenical "tough-pitch" material. Figs. 7 and 8 illustrate the change which has taken place, and it certainly appears as if oxide is penetrating into the metal through grain boundaries, and that small grains of oxide have been replaced by larger ones, consequent upon a slight solubility of cuprous oxide in copper. Near the edges of the specimens in both "tough-pitch" varieties a

TABLE IV.—*Wöhler Tests carried out on Amsler Machine.*

Speed of revolution of bars, 1,760 revs. per minute.
Test-bars 7 in. long, turned over a length of 3 in. to a diam. of 0·38 in.

Sample.	Treatment before Testing.	Stress in Tons per sq. in.	Number of Revs. to Fracture.
1	As received	7·56	752,920
	" "	6·83	6,639,720
	½ hr. in hydrogen at 900 deg. C.	7·69	344,750
	" " "	6·70	376,640
2	As received	6·83	698,520
	" "	6·61	3,144,080
	" "	6·28	6,103,280
	½ hr. in hydrogen at 900 deg. C.	6·29	2,122,030
	" " "	6·00	2,350,570
3	As received	8·32	4,599,060
	" "	8·06	1,207,730
	½ hr. in hydrogen at 900 deg. C.	8·32	321,980
	" " "	7·60	1,767,230
4	As received	6·64	565,320
	" "	5·39	1,446,790
	½ hr. in hydrogen at 900 deg. C.	6·28	8,590
	" " "	5·15	8,900
5	As received	7·69	530,700
	" "	6·31	8,489,370
	½ hr. in hydrogen at 900 deg. C.	5·75	61,080
	" " "	5·73	2,560

TABLE V.—*Izod Tests.*

Sample.	Treatment before Testing.	Energy Absorbed in ft.-lb. Average of Six Tests.	Remarks.
1	As received	43	Unfractured. No sign of cracks. Test-piece deformed through 49·5 deg.
	½ hr. in hydrogen at 900 deg. C.	33	Unfractured. No sign of cracks. Test-piece deformed through 52·5 deg.
2	As received	38	Unfractured. No sign of cracks. Test-piece deformed through 51 deg.
	½ hr. in hydrogen at 900 deg. C.	35	Unfractured. No sign of cracks. Test-piece deformed through 52·5 deg.
3	As received	42	Unfractured. No sign of cracks. Test-piece deformed through 51 deg.
	½ hr. in hydrogen at 900 deg. C.	38	Unfractured. No sign of cracks. Test-piece deformed through 52 deg.
4	As received	33	Unfractured. Faint signs of cracks. Test-piece deformed through 52·5 deg.
	½ hr. in hydrogen at 900 deg. C.	21	Nearly fractured and easily fractured in the hand. Test-piece deformed through 54 deg.
5	As received	34	Unfractured, but small cracks. Test-piece deformed through 51·5 deg.
	½ hr. in hydrogen at 900 deg. C.	3·0	All fractured in machine. Coarse cracked fracture.

certain amount of abnormal grain growth has taken place, and this is illustrated in Fig. 10. This penetration of oxide coupled with grain growth probably causes the firmly adherent character of the scale.

Conclusions.—(1) The phosphorus present in commercial copper which has been deoxidised with this element does not impair the mechanical properties of the metal. Three lots containing up to 0·2 per cent. of phosphorus were extremely strong, quite ductile, and more resistant to alternating stresses than "tough-pitch" varieties which were free from phosphorus.

(2) Deoxidised low arsenical, high arsenical, and 1·5 per cent. nickel-copper containing up to 0·014 per cent. of oxygen withstand severe gassing treatment, which would ruin "tough-pitch" metal.

(3) Deoxidised copper containing 1·5 per cent. of nickel is more resistive to harmful influences arising from severe heating in either reducing or oxidising atmospheres than are either "tough-pitch" (arsenical or non-arsenical) or deoxidised arsenical coppers.

TABLE VI.

Sample.	Treatment.	Number of Blows before Fracture.
1	As received	2,531
	After ½ hr. in hydrogen at 900 deg. C. ..	3,155
2	As received	1,170
	After ½ hr. in hydrogen at 900 deg. C. ..	3,312
3	As received	964
	After ½ hr. in hydrogen at 900 deg. C. ..	1,836
4	As received	1,135
	After ½ hr. in hydrogen at 900 deg. C. ..	287
5	As received	843
	After ½ hr. in hydrogen at 900 deg. C. ..	40

TABLE VII.—*Scaling Experiments.*

All specimens heated at 750 C. in an electric muffle.

Treatment.	Sample.	Results.
A. Pieces 3 in. long heated 10 hrs. Cooled, scraped with a bit of chip and loss in weight determined.	1	Scale peeled easily and amounted to 2·78 oz. per square foot.
	2	Scale peeled easily and amounted to 2·88 oz. per square foot.
	3	Scale peeled easily and amounted to 2·27 oz. per square foot.
	4	Scale penetrated too deeply, and was too adherent to be peeled off.
	5	Scale peeled off fairly cleanly and amounted to 3·34 oz. per square foot of metal surface.
B. Pieces 1 in. long heated 2 hrs. Quenched in water, repeatedly tapped until all scale removed	1	Scale amounted to 3·18 oz. per square foot of metal.
	2	Scale amounted to 2·90 oz. per square foot of metal.
	3	Scale amounted to 2·23 oz. per square foot of metal.
	4	Scale amounted to 2·60 oz. per square foot of metal.
	5	Scale amounted to 3·08 oz. per square foot of metal. Loss in weight determined.
C. Pieces 1 in. long heated ½ hr. in crucibles covered with light-fitting lids.	1	Increase in weight calculated to Cu_2O = 0·80 oz. per sq. ft.
	2	Increase in weight calculated to Cu_2O = 0·78 oz. per sq. ft.
	3	Increase in weight calculated to Cu_2O = 0·59 oz. per sq. ft.
	4	Increase in weight calculated to Cu_2O = 0·83 oz. per sq. ft.
	5	Increase in weight calculated to Cu_2O = 0 78 oz. per sq. ft.

Actually, the tensile strength of this nickel-copper is vastly improved, its hardness greatly increased, no brittleness is developed and it preserves a high ductility after severe gassing treatment.

(4) The nickel-copper referred to in conclusion (3) oxidises less rapidly than any other variety tested. The "tough-pitch" and the deoxidised varieties, not containing nickel, oxidise approximately to the same extent, but when the "tough-pitch" varieties scale the oxide penetrates into the metal—more particularly so in the case of non-arsenical "tough-pitch" copper, on which a very rigidly adherent scale is formed.

It follows that "tough-pitch," non-arsenical copper will give most trouble in hot-working operations where it is desired to avoid entanglement of scale in the metal.

(5) The resistance which 1·5 per cent. nickel-copper possesses to gassing, as well as its augmented hardness and strength resulting from high-temperature treatment, render it very suitable for engineering, and particularly for locomotive parts.

THE LIMITING POSSIBILITIES IN STEAM PLANTS.*

By PROFESSOR A. L. MELLANBY D.Sc., and PROFESSOR WILLIAM KERR, Ph.D.

(*Continued from page* 303.)

The Pressure Limits.—Having derived some indication of an ultimate upper temperature limit, it becomes necessary to examine the factors that influence the pressure considerations. The features of this problem are entirely different from the last. No questions regarding materials arise. The problem involves the properties of steam, the thermodynamics of steam cycles, and the inherent characteristics of steam plants.

In our study of this matter we require to consider only those influences that are controlled or affected by pressure. Factors which have a roughly similar effect at all pressures may be ignored. On considera-

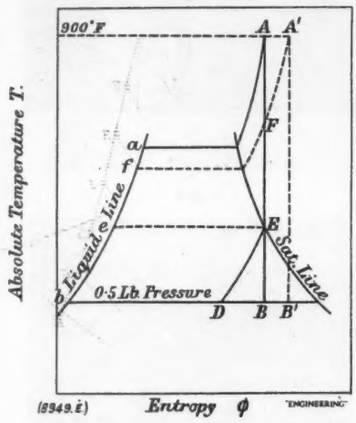


FIG. 5. IDEAL CYCLES.

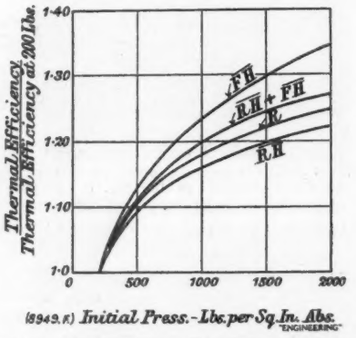


FIG. 6. INFLUENCE OF PRESSURE ON IDEAL CYCLE EFFICIENCIES.

Curve R.	Ideal Rankine cycle.
Curve $\overline{FH}$.	Ideal feed heating cycle.
Curve $\overline{RH}$.	Ideal single stage reheating cycle.
Curve $\overline{RH} + \overline{FH}$.	Combination reheating and feed heating cycle.

tions quite independent of pressure, we have established 900 deg. F. as the upper temperature limit. Hence, this will be common to all pressures. Similarly, the vacuum condition may be taken common to all cases, and for the merely comparative processes involved in our work, we may take the back pressure at 0·5 lb. per square inch absolute. We are thus to examine pressure effects between the limits of 900 deg. F. and 0·5 lb. absolute, in order to find whether there is any limiting pressure. The field between 200 lb. and 2,000 lb./in.² may be searched for this purpose.

We are not at the moment concerned with absolute thermal efficiency values, but with the rise or fall of efficiency curves with initial pressure of operation. Hence, it may be taken that, for any specified cyclic process, the efficiency with a 200 lb./in². initial pressure is unity, and the variation with increasing pressure is then more readily observed without the trouble of considering any change in the basis value. Thus the ideal Rankine cycle—shown by *ba*AB in Fig. 5—gives the rising curve marked R in Fig. 6. The advantage of high pressure in this simple case is, therefore, obvious. The rate of improvement decreases somewhat as the pressure increases, but the improvement itself is continuous.

If we examine the ideal case of extraction feed heating from the point at which the adiabatic line of the Rankine cycle crosses the saturation line—cycle *ba*AED of Fig. 5—we obtain the curve marked $\overline{FH}$ of Fig. 6. The operation in this case involves infinitesimal feed-heating steps and the thermal efficiency is determined from :—

$$\epsilon = \frac{H_A - h_e) - T_B(\phi_E - \phi_e)}{H_A - h_e} \quad . \quad . \quad (1)$$

where H and *h* are, respectively, total heats of steam and water; the suffix on any symbol denoting the point in Fig. 5 at which the value is taken. It is seen from Fig. 6 that the increase of efficiency with pressure is more pronounced than for the Rankine cycle, and well maintained over the whole range.

This feed-heating cycle is, of course, somewhat arbitrary as well as ideal. Slightly different results could be obtained by carrying the highest "tap-off" point into the superheat field. But this is hardly worth following out as these simple cases are only to provide starting ideas and it is sufficiently clear that a feed-heating process superposed on the straight Rankine cycle gives improved results with pressure.

The single-step reheating cycle is indicated by *ba*AFA′B′ in Fig. 5, and its efficiency is given by

$$\epsilon = \frac{(H_A - H_{B'}) + RH}{(H_A - h_b) + RH} \quad . \quad . \quad (2)$$

Here, however, the efficiency is dependent on the amount of the reheat, RH or $(H_{A'} - H_F)$; or, expressed otherwise, on the pressure at which reheating takes place. There is, for any one pressure of supply, a best pressure for reheating, which can be determined easily enough by calculation and plotting. The determination of the best reheating pressure is then a preliminary to the calculation of the efficiency; and when the reheating step has been so fixed, the curve marked $\overline{RH}$ in Fig. 6 is obtained as showing how the efficiency increases with pressure. It will be noticed that a fairly steady increase still holds, although the rate of increase is somewhat less pronounced than in the Rankine cycle. It is unnecessary for our present preliminary purposes to discuss the influences of multi-step reheating, as the effects differ in only a minor degree from those shown for the single stage.

It is so far clear that the ideal reheating cycle is less favourably influenced by pressure than the ideal feed-heating cycle; but in actual plants these operations will occur together, as both offer distinct advantages. The feed-heating process gives a definite thermodynamic gain, while reheating provides a theoretical gain together with a beneficial influence on the machine efficiency. It follows that when both processes are employed, the reheating will have the effect of reducing the rate of increase with pressure shown by feed heating alone. Thus we may assume for illustration a combination cycle of one stage reheating together with a limited number of feed-heating steps covering the range up to the pressure of reheat. That is, the upper limit for extraction is point F of the reheating cycle in Fig. 5, and the several other feeding points are distributed along the adiabatic A′B′. The efficiency in this case is determined from

$$\epsilon = \frac{H_A - H_{B'} + RH - x_1 \cdot RH - \Sigma x\,(H - H_{B'})}{H_A - h_f + RH - x_1 RH} \quad . \quad (3)$$

where the *x*'s represent the fractions extracted for feed heating and x_1 refers to the heater at F. All heaters come under the summation sign in the numerator. The number of heaters has been varied with the heating range as fixed by F, starting with three for the 200-lb. cycle and increasing to five for the 2,000-lb. cycle. The result is shown by the curve $\overline{RH} + \overline{FH}$ in Fig. 6. This is almost midway between the curves $\overline{RH}$ and $\overline{FH}$, and shows that with a combination cycle we cannot expect to get so high a rate of increase with pressure as is indicated by the ideal wet field feed-heating cycle alone.

We see, then, that in the cases considered there is little indication of any real pressure limit; 2,000 lb./in.² is better than 1,500 lb./in.² in all of them. But a noticeable feature of the curves in Fig. 6 is that the period of rapid improvement with pressure is within the first 1,000 lb. of increase. The only curve still maintaining a high rate of rise in the second 1,000 lb. is $\overline{FH}$, and we have shown that it is the least representative. But the feature of Fig. 6 and the methods behind it provide only a first view of the matter. The discussion has followed fairly obvious lines, but its conclusiveness is weakened by the idealistic nature of the cycles considered and their rather complete dissociation from those actual engine processes for which they express the limit cases. We must derive

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders at Newcastle-upon-Tyne, on February 27, 1925.

some ideas regarding the influence of pressure on the essential machine efficiencies before reasonable judgment can be reached in the matter.

It is obvious that, as the initial pressure is increased, there is an increasing proportion of the expansion in the wet field as well as an increasing part in the high-pressure field. That is, at both ends of the machine there would apparently be detrimental influences at work. The effect of wetness may be allowed for by means of the usual rule of multiplying the stage efficiency for dry steam by the dryness fraction of the stage. The effect of pressure requires other considerations.

If the heat available to a stage of the turbine is D H ϕ the stage efficiency may be expressed as

$$\eta = \frac{\text{D H}\phi - \text{Stage Losses}}{\text{D H}\phi}$$

$$= 1 - \left\{ \frac{\text{Nozzle Loss}}{\text{D H}\phi} + \frac{\text{Blade Loss}}{\text{D H}\phi} + \frac{\text{Disc Loss}}{\text{D H}\phi} + \frac{\text{Leakage Loss}}{\text{D H}\phi} \right\}$$

$$= 1 - (r_n + r_b + r_d + r_l) \quad . \quad . \quad . \quad . \quad (4)$$

Consider the disc loss first. If the blade speed is s, the diameter d, the steam flow M, and the specific volume V, then the fractional loss due to rotation is given by

$$r_d \propto \frac{s^3 . d^2}{\text{M} . \text{V} . \text{D H}\phi}$$

But $s \propto \sqrt{\text{D H}\phi}$, and $d \propto \frac{s}{\text{N}}$ where N represents the speed of rotation, hence

$$r_d \propto \frac{\text{D H}\phi^{\frac{3}{2}}}{\text{N}^2 . \text{M} . \text{V}}$$

We may assume that DH ϕ is alike in all cases and that M is practically so; then

$$r_d \propto \frac{1}{\text{N}^2 . \text{V}},$$

so that to keep the disc loss a constant fraction at all conditions it would be necessary to make

$$\text{N} \propto \frac{1}{\sqrt{\text{V}}}$$

Now it is possible to give N this order of variation by adopting geared high pressure turbines. It seems quite probable that such an arrangement may become standard for high pressure plants. This consideration of the disc loss shows up the necessity most clearly, but the other elements of the loss totals also benefit to some extent from the reduction of diameter that follows from increase of speed.

If P_1 and V_1 represent initial steam conditions in any case, we may assume that the speed of the high-pressure turbine is arranged to suit

$$\text{N} \propto \frac{1}{\sqrt{\text{V}_1}} \propto \sqrt{\text{P}_1}$$

and accept the consequences, knowing that this is probably the most favourable condition in an examination of pressure effects. The main turbine operating over the usual pressure range will, however, have the same speed in all cases, so that we have further to assume that below, say, 200 lb., pressure, N is constant.

Hence, in the general case of the high pressure turbine plant, we have to allow that expansion down to 200 lb. pressure is carried out in a small geared turbine of speed

$$\text{N} \propto \sqrt{\text{P}_1}$$

and below that pressure expansion takes place in a machine at a value of N which is constant and independent of initial conditions.

Suppose now that at standard conditions, say 100 lb. / in^3 dry steam,

$$r_d = \text{R}_\text{D}$$

and is assessable. Then for all conditions above 200 lb. when initial pressure is P_1 and if the standard speed below 200 is N^1, we should have

$$\frac{r_d}{\text{R}_\text{D}} = \left(\frac{\text{N}^1}{\text{N}}\right)^2 \left(\frac{4{\cdot}45}{\text{V}}\right) = \left(\frac{200}{\text{P}_1}\right) \left(\frac{4{\cdot}45}{\text{V}}\right)$$

or

$$r_d = \frac{900}{\text{P}_1 \text{V}} . \text{R}_\text{D} \quad . \quad . \quad . \quad (5)$$

For all conditions below 200 lb., N^1 and N are alike, and

$$r_d = \frac{4{\cdot}5}{\text{V}} . \text{R}_\text{D} \quad . \quad . \quad . \quad (5a)$$

These two equations allow us to deal with the variations of disc loss due to pressure. The principle employed, however, is such that there is no serious variation due to this cause, but we require to accept also the consequent variations in the other loss factors.

The leakage loss factor might be reasonably assumed as

$$r_l \propto \frac{d}{\text{M} . \text{V}}$$

or, introducing N and allowing M to be constant

$$r_l \propto \frac{1}{\text{N} . \text{V}}.$$

The assumption here is that we can get down to certain minimum working clearances which will not be greatly affected by moderate changes in diameter. Consequently, the leakage areas are as the diameters, and the losses vary as the ratio of leakage areas to working areas. Again, we have the conditions of N $\propto \sqrt{\text{P}_1}$ above 200 lb., and constant below that limit; so that if

$$r_l = \text{R}_\text{L}$$

at the assumed standard condition of 100 lb./in^2 dry, we get by the same process as before

$$\frac{r_l}{\text{R}_\text{L}} = \left(\frac{200}{\text{P}_1}\right)^{\frac{1}{2}} . \frac{4{\cdot}45}{\text{V}}$$

or

$$r_l = \frac{63}{\text{V}\sqrt{\text{P}_1}} \text{R}_\text{L} \quad . \quad . \quad . \quad . \quad (6)$$

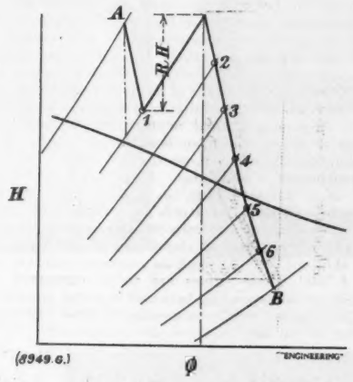


FIG. 7. ACTUAL CYCLE ON THE H — ϕ CHART.

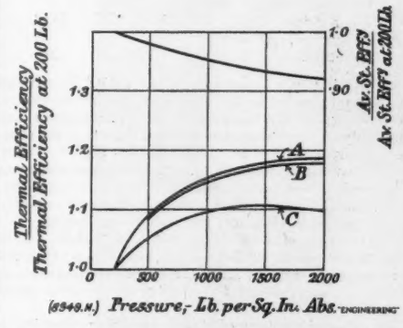


FIG. 8. INFLUENCE OF PRESSURE ON ACTUAL CYCLE EFFICIENCIES.

for stage conditions above 200 lb. pressure, and

$$r_l = \frac{4{\cdot}5}{\text{V}_1} . \text{R}_\text{L} \quad . \quad . \quad . \quad . \quad (6a)$$

for conditions below 200 lb.

This brings us now to the question of the variation of the nozzle and blade losses, which are much more difficult to assess. This is, in reality, a question of the scale effect on the steam flow losses. When we recognise the uncertainty that exists regarding the nature and proportion of the detail losses in these elements the form of the perplexity becomes more evident.

In nozzle action, a considerable proportion of the total loss—about 70 per cent. and upwards—is dependent on boundary influences. This fact is rather clearly shown in simple nozzle experiments and is substantiated by such full-scale tests as those carried out on impulse nozzles by the Institution of Mechanical Engineers Commitee. This part of the loss is, therefore, influenced by nozzle size. The remaining losses must be the summation of entrance, curvature and outlet effects and the incidence of size of these is not at all clear. Generally it might be conceived that the essential ratios influencing these losses remain reasonably constant as the steam passage dimensions alter.

The same might apparently be said of the boundary effects in nozzles, since the length might maintain a definite relation to the passage widths, but in actual construction, as the pressure increases, the lengths will be less affected than the areas, and the tendency will be for the nozzle boundary losses to follow the flow area changes.

We will assume, then, that a large proportion—say about 70 per cent.—of the nozzle losses are so influenced and that a small part—say about 25 per cent.—of the blade losses are likewise affected. The remaining flow losses we allow constant. The uncertainty of overcharge in the parts allowed to vary may be held as balancing against the uncertainty of constancy in those parts in which no change is considered. It would obviously have been simpler to avoid the whole question by assuming the fractional flow losses constant throughout; but there is an instinctive feeling that with the small spaces necessitated by high pressure the flow losses will be increased somewhat, and the method adopted is a roughly approximate procedure to allow for this, guided to some extent by available knowledge of the subject. It may be developed as follows:—

If l is the length of a steam way and $\sqrt{\text{A}}$ is taken as characteristic of its lateral dimensions, where A is the area of passage, then the fractional boundary loss incurred could be considered as proportional to $l/\sqrt{\text{A}}$. But if p represents the pitching of the passages, we have that

$$\frac{d . \text{A} .}{p} \propto \text{M} . \text{V}.$$

and hence, if M is taken as constant,

$$\text{Loss} \propto \frac{l}{\sqrt{p}} . \sqrt{\frac{d}{\text{V}}}$$

We may now assume that

$$l \propto \sqrt{p}$$

which is equivalent to saying that if the pitch is maintained constant so is the length, or, otherwise, that any reduction of the pitch to suit reduced areas is accompanied by a somewhat slower reduction of length. Expressed thus, the argument already advanced appears at once clearer and more justifiable.

We have then that the varying part of the nozzle and blade loss changes with $\sqrt{d/\text{V}}$ and, consequently,

$$r_n + r_b = \text{C} + r^1 = \text{C} + c \sqrt{\frac{d}{\text{V}}}$$

where C and c are constants. Introducing R^1 as the value of r^1 at the standard conditions, putting I/N in place of d and reducing, in the manner already illustrated by the previous cases, we get finally that

$$r^1 = \frac{8}{\text{V}^{\frac{1}{2}} . \text{P}_1^{\frac{1}{2}}} \text{R}^1 \quad . \quad . \quad . \quad (7)$$

for conditions above 200 lb. pressure, and

$$r^1 = \frac{2{\cdot}1}{\text{V}^{\frac{1}{2}}} \text{R}^1 \quad . \quad . \quad . \quad (7a)$$

for conditions below that limit.

We have, then, established a distribution of various losses which may permit a general view of the influence of pressure. The expression for stage efficiency given descriptively by (4) now becomes more fully and exactly

$$\eta = q e \left[1 - \left\{ \text{C} + \frac{8 \text{R}^1}{\text{V}^{\frac{1}{2}} . \text{P}^{\frac{1}{2}}} + \frac{900 \text{R}_\text{D}}{\text{P}_1 \text{V}} + \frac{63 \text{R}_\text{L}}{\text{V} . \text{P}_1^{\frac{1}{2}}} \right\} \right] \quad (8)$$

for pressure above 200 lb., and

$$\eta = q \left[1 - \left\{ \text{C} + \frac{2{\cdot}1 \text{R}^1}{\text{V}^{\frac{1}{2}}} + \frac{4{\cdot}5}{\text{V}} \left(\text{R}_\text{D} + \text{R}_\text{L} \right) \right\} \right] \quad (8a)$$

for lower values.

The symbol q represents the dryness fraction of the steam and will affect all stages working in the wet field; e stands for gearing efficiency (say 0·97) and will affect all high-pressure stages operating behind gearing. This factor is a necessary consequence of allowing the introduction of gearing as the presumably best method of meeting the effects of high pressure.

It remains to assess the values of the R's. Since we are dealing entirely with variations of effects, it has been considered sufficient to assume

$$\text{C} = 0{\cdot}10, \quad \text{R}^1 = 0{\cdot}07, \quad \text{R}_\text{D} = \text{R} = 0{\cdot}03$$

so that in the "standard" stage operating at 100 lb. per square inch, dry, we find

$$\eta = 1 - (0{\cdot}10 + 0{\cdot}07 + 0{\cdot}06) = 0{\cdot}77$$

This may appear slightly high but some points influencing stage efficiency have been ignored, while it must be clearly appreciated that comparative results are alone being sought. It should also be realised that it is not directly the variation of stage efficiency along a given expansion line that affects our final results so much as the variation of the average efficiency for different expansion ranges. Hence any faults in equations (8) will be greatly minimised in the conclusion.

It will be noticed that all arguments have been based

on the impulse turbine type. This is natural since it is the simpler to discuss; but the reaction type should be subject to somewhat similar variations. Thus, for example, the fraction charged above to disc and leakage losses might be considered to be due to the latter cause alone. The variation would still remain much the same.

Having decided on the efficiency influences, the further procedure is fairly obvious. The best amount of reheat on the single-stage reheating cycle has already been determined for the various initial pressures. The limit of feed heating is assumed to be at the pressure of reheating, and a sufficient number of heaters have been taken in each case to cover the range in about 50 deg. F. steps. The adiabatic lines for operation before and after reheating are obtained and, by dividing up into an arbitrary number of steps, conditions are derived from which a series of representative stage efficiencies can be determined by the application of equations (8). Reheat factors are then introduced and actual expansion lines established. On these the feed-heating points are fixed, and the thermal efficiency can then be calculated. On the total heat-entropy diagram the operations take the form indicated by the sketch Fig. 7, and the thermal efficiency follows from

$$\epsilon = \frac{H_A - H_B + R\,H - x_1\,.\,R\,H - \Sigma x\,(H - H_B)}{H_A - h_1 + R\,H - x_1\,R\,H.} \quad (9)$$

which is similar to equation (3), x and H referring to the marked points 1, 2, 3, &c., which denote the feed-heater positions.

Faced with considerable calculation and a shortage of time, the authors have permitted themselves the luxury of a few special methods of approximation which, however, should not affect the essential relative influence of pressure. The result of the investigation is shown by curve A in Fig. 8, and seems little enough for such a mass of argument and figuring. While no definite limit discloses itself herein, it has become clear that the last 500 lb. offers but little prospect. The curve tends definitely to a flat top and the conclusion is obvious. The upper curve in Fig. 8 gives an idea of how the average stage efficiency alters throughout the range of pressure according to the analysis carried out.

The curve A in Fig. 8 represents the result obtained from the analysis of the cyclic processes in so far as they apply to the actual engine operations. Influences external to this involve the feed-pump work and the boiler efficiency. The former is of no moment at normal pressures, but as the pressure increases it produces a noticeable reduction of thermal efficiency. By deducting about twice the theoretical feed-pump work from the net work of the cycle the curve B in Fig. 8 would be obtained. This is similar in form to A and shows even more clearly that pressures above 1,500 lb./in.^{2} offer no advantage.

If the boiler efficiency were assumed constant over the whole range, there would be no influence of pressure and the form of curve B would again apply—although, of course, lowered in position. This would necessitate, however, that the outlet flue gas temperature would remain the same at all pressures. The actual outlet temperature will depend on the extent of the air preheating, but since this air temperature is a furnace limitation it should be the same at all pressures. Hence the outlet gas temperature would only be the same at all pressures if it were reduced to the same value at the boiler outlet. This would necessitate a considerable variation in the difference between the outlet-gas and inlet-water temperatures. We could, then, either get a constant chimney loss at the expense of heating surface, or an increasing chimney loss with the same "temperature head." This last would represent an extreme condition, perhaps, but we may take it for illustration. When applied, it results in a fall of about 1½ per cent. in boiler efficiency per 500 lb. increase, and gives curve C of Fig. 8. Even if we allowed only half of this rate of efficiency fall as a mere assumption apart from any argument as to cause, the form of the resulting curve that would be obtained would be very similar to C.

Curves B and C, then, represent two different forms arising out of the consideration of two extremes in the influence of pressure on boiler efficiency, superposed on the influence of pressure on turbine efficiency. The former shows that the best pressure is about 1,500 lb./in^2; the latter that it is between 1,000 and 1,500 lb./in^2.

It is clear that practical considerations would tend to keep the pressure low. If attention were given to that fact, 1,000 lb./in^2 might appear as sound a choice as any; 1,500 lb./in^2 is certainly on the high side. It follows that 1,250 lb./in^2 must be close to a true upper limit on any consideration and we, therefore, choose that value. It could, however, with a fair show of reason, be admitted that there is too little prospective gain to justify actual advance beyond 1,000 lb./in^2.

(To be continued.)

IMPROVING THE PROPERTIES OF ALUMINIUM ALLOY CASTINGS.*

By S. L. ARCHBUTT, F.I.C.

THE present paper describes some experiments on methods of improving the properties of aluminium alloy castings. This work is part of the programme of research on light alloys being carried out at the National Physical Laboratory for the Engineering Research Board of the Department of Scientific and Industrial Research.

Aluminium alloys cast in sand are in general inferior in mechanical properties and general soundness to corresponding castings made in metal or chill moulds. The slower rate of solidification which occurs in a sand-mould produces a coarse grain which is in itself detrimental to mechanical properties. These effects are, however, usually accentuated by general unsoundness, commonly of the type known as "pin-holing." The "pin-holes" are small cavities more or less spherical in shape, fairly uniformly disseminated through the body of the casting; they are revealed on machining, as shown in Fig. 1. Coarseness of grain and pin-holing are accentuated in sand-castings by high pouring temperatures. If melting and pouring temperatures are kept low, considerable improvement can be effected in respect of these defects.

Under the most carefully controlled conditions, however, employing normal foundry practice and treatment of melts, it has not been found possible at the Laboratory to effect more than a certain degree of improvement in soundness. Using the 1 in. diameter bar as a standard form of casting, cold dry sand moulds, melting temperatures not exceeding 730 deg. C. and ample risers and runners, the general order of density of cast bars of aluminium alloy "Y"† (with the skin on) is 2·735, with an occasional value as high as 2·750. These values are to be compared with 2·780 for corresponding bars cast in metal moulds.

The average tensile properties of these two classes of bar in the cast condition are as follows:—

	Sand Cast.	Metal Cast.
Density with skin on	2·735	2·798
Yield stress, tons per square inch	—	11·4
Ultimate stress, tons per square inch	10·5	14·8
Elongation, per cent. on 2 in.	0·5	2·5

The fact that pin-holing can be eliminated in castings of normal thickness by employing metal moulds is well known at the National Physical Laboratory and probably in most aluminium foundries. It is the case, for example, with 1 in. diameter bars of "Y" alloy and other aluminium alloys. The fact has also been observed at the Laboratory that very slow solidification, such as occurs when a melt is allowed to solidify in the pot in the furnace, also inhibits pin-holing.

In the case of a sand-cast piston in "3L11" alloy sent to the Laboratory for examination, which exhibited profuse pin-holing on machined surfaces, a portion was re-melted and caused to solidify slowly in a small crucible.

A polished section of this ingot was practically free from pin-holing and gave a density of 2·812 compared with 2·769 for material from the piston. It is evident, therefore, that both rapid and very slow solidification inhibit "pin-holing," and that some intermediate rate such as occurs in a sand mould, is most favourable for its formation. These facts together with others led to the conviction that the cause of "pin-holing" is occluded gas, and particularly that portion of gas which is liberated during the act of solidification.

It appeared that if solidification was sufficiently rapid, as in a metal mould, the occluded gases in the melt were not liberated, but retained in solution in the solidified alloy. If solidification were sufficiently slow, the gas was liberated and enabled to free itself from the solidifying melt, while at intermediate gates it was liberated from solution, but entrapped in the form of minute bubbles causing pin-holing. It appeared probable, therefore, that if a melt were slowly solidified it would largely rid itself of occluded gas, and that castings poured from the remelt would exhibit improved soundness, providing that not much fresh gas was absorbed during remelting.

Experiments on these lines were immediately successful.

The treatment consisted in allowing a melt to solidify slowly in the uncovered crucible (Morgan Salamander) in the furnace. As soon as it was solid and without further cooling, the crucible was covered, the furnace relighted, and the metal remelted, raised to the required temperature, and castings poured. From melts of 10-20 lb. of "Y" alloy treated in this way, 1 in. diameter bars cast in sand were obtained, giving, without any machining, density of 2·78 and higher.

On light machining an almost entire absence of pin-holing was observed, the surface appearance closely resembling that of a chill-cast bar. Bars from these melts gave very uniform ultimate stress, varying from 11·3 to 11·8 tons per square inch (as cast), representing an increase in strength of the order of 10 per cent. over that of sand-cast bars from untreated melts.

The improved soundness obtained by the treatment above described is illustrated by bar sections 2030 and 2046 in Fig. 2. Occasionally during the above treatment small explosions occurred at the surface of the melt, suggesting that inflammable gas was being ejected and igniting.

Preliminary ingotting of aluminium alloy melts may therefore be decidedly advantageous provided that the rate of solidification of the ingots is slow enough, but marked improvement is not to be expected from ordinary ingotting in metal moulds. The results obtained from a 20-lb. melt of "Y" alloy ingotted in chill moulds, remelted and poured, confirm this. Four 1 in. diameter sand-cast bars from this melt gave (with the skin on) an average density of 2·744 and ultimate stress of 11·29 tons per square inch, representing a slight improvement only on results from normally treated melts not ingotted. Further experiments have been made with "Y" alloy, in which treatment of melts on the lines indicated above have been modified as follows:

1. The slowly solidified and remelted alloy was ingotted in chill and then remelted. A 12-lb. melt was treated in this way, and four 1 in. diameter bars cast in sand. Two of these were tested with the following excellent average results:

Density unmachined	2·774
Ultimate stress, tons per square inch....	12·20
Elongation, per cent. on 2 in.	1·0

2. Slow solidification and remelting was repeated three times on a melt before pouring castings. Unsatisfactory results were obtained from a 10-lb. melt treated in this way.

3. Slow solidification was applied to copper hardener alloys only. Some excellent results were obtained from melts treated in this manner.

In the majority of the experiments described above, stirring or other disturbance of the melt liable to introduce gas was purposely avoided after remelting subsequent to slow solidification.

Analytical results on small ingots poured before and after the pouring of test-bar moulds, indicate some tendency towards concentration of added elements in the lower layers of the remelted alloy. In anticipation of this a 10-lb. melt was slowly solidified, remelted, and the remelt stirred in a normal manner before pouring. The density, tensile strength, and appearance of machined surfaces of bars from this melt were up to the general standard reached with unstirred melts.

It would appear, therefore, that careful stirring after slow solidification may be employed without detrimental effects.

In all the melts described above, notched-bar aluminium of high purity was employed, giving the following analytical results:

	Aluminium "T" per cent.
Iron	0·16
Silicon	0·16
Copper	trace
Aluminium (difference)	99·68

This metal was tough and ductile under the hammer, and the bars required many reversed bending blows to fracture them at the notches. In the course of the experiments with this metal, a consignment of aluminium also in the form of notched-bar was received at the laboratory. This metal was labelled "Made in Norway," and gave the following results on analysis:

	Aluminium "U" per cent.
Iron	0·21
Silicon	0·29
Copper	trace
Aluminium (difference)	99·50

Aluminium "U" is seen to be of high purity but not equal to aluminium "T."

Under the hammer this metal behaved totally differently from "T" metal, breaking quite short in a brittle manner. Employment of aluminium "U" immediately upset the regular and consistent character of results, as shown in Table I.

It will be seen that on a first application of the slow solidification treatment very inferior results were obtained from two melts of 12 and 20 lb. respectively: also from a 20-lb. melt, YV2017, in which the copper hardener only had been treated before use, a method which when using "T" aluminium had given good results. On remelting YV2017 and again applying

* Paper read before the Institute of Metals, London, on Wednesday, March 11, 1925. Abridged.

† Copper 4, nickel 2, magnesium 1·5 per cent., aluminium remainder.

the slow solidification treatment, however, excellent density and soundness were obtained from bars poured at 650 deg. C.

It would appear, therefore, from these results that with certain grades of metal more than one application of the treatment in question may be necessary. In this particular instance the aluminium was suspected of containing an unusual amount of occluded gas. In order to obtain evidence in the matter some melts of this metal alone were made and 1-in. diameter bars cast in sand under conditions similar to those employed with the melts already described. The density of the bars unmachined was determined, and they were then lightly machined and examined for appearance.

Particulars and results of these melts are given in Table II.

The results show that (1) as ordinarily melted and cast, this particular aluminium gives sand-cast bars of abnormally low density.

(2) On remelting and applying slow solidification treatment normal density is obtained, accompanied by great improvement in the appearance of machines surfaces.

(3) Repeating the slow solidification treatment is detrimental.

(4) The density of the notched bar, as supplied, is normal and illustrates the fact, previously pointed out, that by rapid solidification occluded gas is retained in solid solution and has little, if any, effect on density.

Other Experiments.—Some experiments have been made with a form of casting shown in section in Fig. 3. This form was chosen as being readily machined all over in a lathe and presenting considerable variation in thickness of section, which was in parts a good deal heavier than a 1-in. diameter bar. The castings were poured bowl uppermost, in dry-sand moulds. The casting weighed approximately 1½ lb. The following results were obtained with "Y" alloy:—

Castings from melts YV1971A and B were halved on the axis PQ, Fig. 3. The pin-holing exhibited on the external machined surface of A was seen to extend completely through the body of the casting, whereas B appeared equally sound throughout. Photographs of these two sections are reproduced in Fig. 4. The difference in appearance of machined surfaces of these two castings is very striking.

In consideration and discussion of the above results, it was suggested to the author by Dr. Rosenhain that the removal of small bubbles of gas liberated and entangled in molten metal or alloy, might be facilitated by passing through the melt an inert gas such as nitrogen. The following experiment was therefore made:—

A melt of 12 lb. of "Y" alloy was made up in the manner described in the paper, employing "U" aluminium. The crucible lid was removed and the melt allowed to cool in the furnace. Commencing at 710 deg. C., a stream of nitrogen of ordinary commercial purity from a high-pressure cylinder was passed through the melt by means of an iron tube, coated with a wash

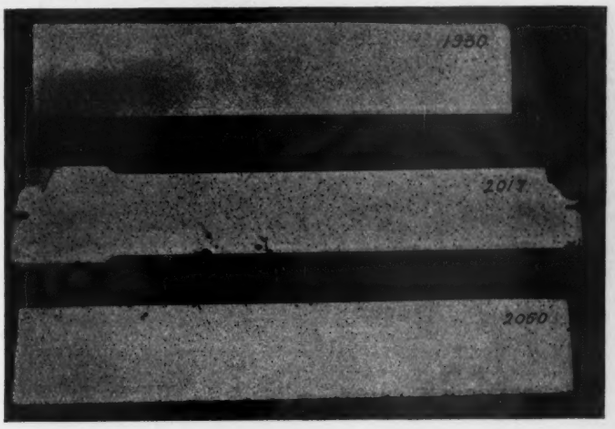
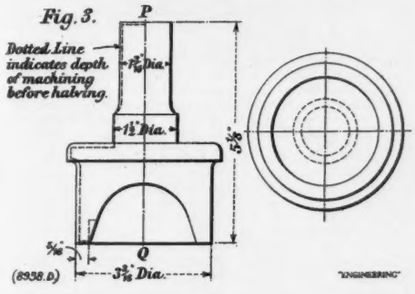


FIG. 1.

Longitudinal Axial Sections of 1-In. Diameter Sand-Cast Bars "Y" Alloy, Machine Finish. (Approximately Two-Thirds Actual Size.)

FIG. 2.

Longitudinal Axial Sections of 1-In. Diameter Sand-Cast Bars "Y" Alloy, Machine Finish. Treated Melts. (Approximately Two-Thirds Actual Size.)



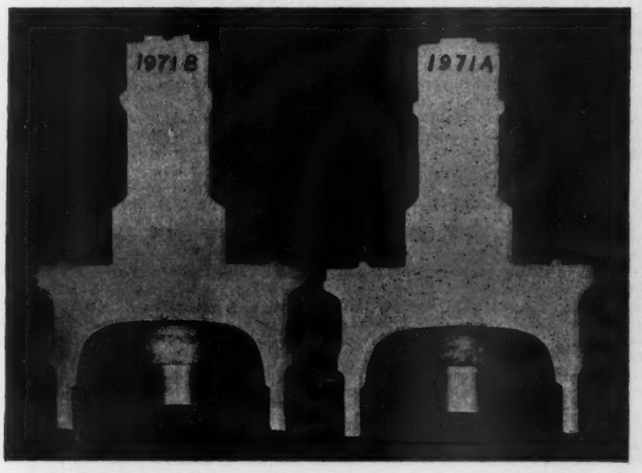


FIG. 4.

Axial Section of Special Casting, Machine Finish. 1971 A Ordinary Melt, 1971 B Treated Melt.

Fig. 5. METHOD OF MOULDING SAND-CAST BARS.

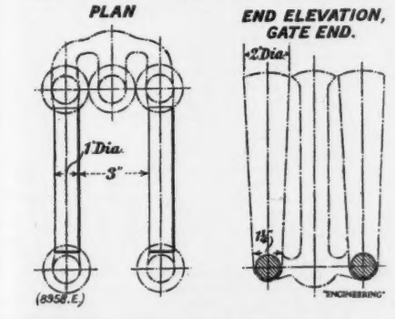


TABLE I.—*"Y" Alloy Melts with "U" Aluminium. Sand-Cast Bars 1 in. diameter.*

Melt No.	Weight. Lb.	Conditions.	Average Density of Bars.	Appearance on Machining.
			Unmachined.	
YV2015	12	Slowly solidified and remelted	2·741	Marked unsoundness and pinholing.
YV2018	20	Slowly solidified and remelted	2·279	Serious unsoundness and pinholing.
YV2017	20	Copper hardener only slowly solidified	2·718	Serious unsoundness and pinholing.
YV2024	12	Ordinarily melted	2·752	Marked pinholing.
YV2030	20	Ingot and scrap from YV2017 remelted and slowly solidified	2·775*	Slight pin-holing.

* A longitudinal section through the axis of one of these bars, finished with a fine milling cut, appeared perfectly sound and free from pin-holing. Bar section, 2030, Fig. 2.

TABLE II.—*Experiments on the Treatment of "U" Aluminium. Sand-Cast Bars 1 in. diameter.*

Mark.	Treatment.	Density Unmachined.	Appearance after Machining.
"Made in Norway"	Section from notched-bar	2·701 2·694	—
V2020 (1) (2)	Ordinary melting	2·639 2·641	General unsoundness, causing poor machine finish.
V2021 (1) (2)	Slow solidification treatment	2·694 2·695	Greatly improved soundness and machine finish.
V2022 (1) (2)	Treatment repeated on ingots and runners, &c., from V2021	2·673 2·676	Somewhat inferior to V2021.
V2023 (1) (2)	Treatment repeated on ingots and runners from V2022	2·671 2·667	Markedly inferior to V2021.

of alundum, extending to the bottom of the crucible. The passage of nitrogen was sufficiently rapid to produce the effect of moderate ebullition of the melt, without ejection of liquid from the crucible. From the commencement of passage of the nitrogen a gas which took fire and burnt with a blue flame was observed to be escaping from the surface of the melt, together with the nitrogen. The melt took approximately 20 minutes to cool from 710 deg. C. to 650 deg. C., and it was during the first 10 minutes or so of this cooling that the inflammable gas was evolved in sufficient quantity to take fire. The melt was held at 650 deg. C. for 15 minutes and then allowed to solidify and cool to 500 deg. C. Nitrogen was passed continuously until the melt appeared solid. The crucible was now covered the contents remelted, and two 1-in. diameter bars poured at 650 deg. C. in sand. These two bars, unmachined, gave the following density values :—

TABLE III.

Melt No.	Treatment of Melt.	Density Lightly Machined.	Appearance after Machining.
YV1971A	Ordinary	2·702	Marked "pin-holing."
YV1971B	Slow solidification applied to remelt of YV1971A	2·763	Sound—no "pin-holing."
YV1972	Slow solidification applied to remelt of YV1971B	2·749	Slightly inferior to YV1971B.

Melt No.	Density.
YV2048 (1)	2·795
YV2048 (2)	2·794

On machining these bars were found to be remarkably sound and free from pin-holing. A longitudinal section through the axis of test-bar YV2048 (2) above, finished with a fine milling cut, is shown in Fig. 2, and illustrates the excellent soundness of these bars. The densities recorded indicate a further marked improvement in soundness over and above the best previously obtained by slow solidification treatment alone. The values are almost equal to the best so far obtained from chill-cast bars from ordinarily treated melts.

Summary.—The experiments and the results obtained from them are to be regarded as indicating the possibilities of a method of treating aluminium and certain of its alloys, which serves to eliminate at all events a considerable proportion of dissolved gas and thus reduces unsoundness, and to a considerable extent removes pin-holing. The process suggested consists in allowing the molten alloy or metal to cool slowly in the crucible in the furnace until it has just completely solidified; it is then remelted, and may be carefully stirred, raised to the pouring temperature, and cast. Ingotting the metal is not satisfactory, as the ingots cool too quickly, and during remelting are too much exposed to the furnace gases.

In a later experiment, passage of an inert gas through the melt during slow cooling and solidification has been found to improve still further the soundness of resulting sand-cast bars.

Slightly anomalous results have been obtained in some cases, and it is not yet clear how far the method is of value in other alloys, whether consisting mainly of aluminium or of other metals. It is evident that much further investigation is required. Meanwhile, the author has learnt, and is authorised to refer to the fact here, that simultaneously and independently Professor C. A. Edwards and Mr. W. E. Prytherch of Swansea, working on the effect of gases in copper (for the British Non-Ferrous Metals Research Association) have discovered a similar effect obtained by solidification in the crucible in the case of pure copper.

The author desires to express his thanks and indebtedness to many of his colleagues of the staff of the Metallurgy Department of the National Physical Laboratory; to Dr. W. Rosenhain, F.R.S., Superintendent of the Department; and to the Aeronautical Research Committee for permission to publish the results contained in the paper.

APPENDIX.

A. *Metals and Hardeners.*—Metals of high purity were used.

Analyses.—Aluminium—Notched bar—analyses are given in the text of the paper.

Copper—Electrolytic cathode plates.

Nickel—Shot, Mond Nickel Co., 99·9 per cent. nickel.

Magnesium—Chill rods. Chemical analysis :—

	Per cent.
Silicon	0·01
Iron	0·08
Copper	0·02
Magnesium (difference)	99·89
	100·00

The copper and nickel were added to the aluminium in the form of "hardener" alloys of aluminium containing 45·7 per cent. copper and 20 per cent. nickel, respectively.

B. *Preparation of "Hardener" Alloys.*—(1) Copper-aluminium (45·7 per cent. copper); (2) Nickel-aluminium (20 per cent. nickel).

(1) The copper is first melted under charcoal and the aluminium added gradually. When the whole of the charge is molten the alloy is thoroughly stirred, skimmed, allowed to cool to 700 deg. C., and poured into notched slabs in chill moulds. It is readily broken up for weighing-out charges.

(2) The nickel hardener is rather more difficult to make. The aluminium is melted and the temperature raised to, and retained at 900 deg. C. until the whole of the nickel is dissolved.

The nickel is added in small quantities at a time in the form of shot. Each charge of nickel must be completely dissolved and the melt stirred before a further addition is made, otherwise a compact mass soluble with difficulty may be formed at the bottom of the crucible which requires a considerably higher temperature and a much longer period of dissolve. The alloy has a considerable temperature range of solidification and is poured into thin notched slab ingots in chill moulds, in order to prevent serious differences of composition arising during solidification.

The alloy is cooled to 850 deg. C. before ingotting. It is readily broken up for weighing-out charges.

C. *Melting—Ordinary Method of Preparing Melts.*—A 100-lb. "Richmond" gas-fired, natural draught furnace is employed, town gas being used. The metal is melted in a Salamander crucible closed with a lid, the crucible being raised to redness before making the initial charge. The aluminium is melted, raised to 730 deg.–750 deg. C., and the nickel hardener added and dissolved. The copper hardener is then added and dissolved. The melt is carefully skimmed and then stirred. The magnesium is next introduced in a few large pieces by means of a Morgan plunger stirrer. The temperature is adjusted until about 20 deg. C. above the desired pouring temperature, when the pot is removed from the furnace. During cooling the melt is carefully skimmed, and when the temperature required is reached, poured. Carbon rods are used for stirring.

D. *Temperatures of Melting and Pouring.*—Care was exercised in all melting operations to prevent the metal exceeding a maximum temperature of 750 deg. C. Castings were poured at 700 deg. and 650 deg. C. respectively, 650 deg. being ultimately chosen as giving superior results.

E. *Moulding.*—Bars were moulded horizontally in sand, two in a box, and run with a 1-in. diam, down-runner terminating in a skim-gate, as shown in Fig. 5.

Risers were placed at both ends of each bar 8 in. from top of riser to mould joint, and tapering from 2-in. diameter at the top to 1¼ in. diameter at the bottom. The sand used consisted of a mixture approximating to half new and half old "Mansfield" red sand, which was graded by passing through a ¼-in. mesh riddle. Moulds were well dried and allowed to cool before running the bars.

EXPERIMENTS ON A SLOTTED AEROFOIL.—Messrs. Handley Page initiated some years ago a wind tunnel research on the properties of slotted wings, having as its object the increase of the maximum lift co-efficient, or, in other words, to obtain the maximum lifting capacity of an aeroplane for a given area of wings. Summaries of these results have been published in the official Reports and Memoranda Nos. 834 and 930. Reports and Memoranda No. 929 entitled "Some Experiments on a Slotted Aerofoil," by H. B. Irving, B.Sc., and A. S. Batson, B.Sc., form a continuation of this work at the National Physical Laboratory on an aerofoil measuring 6 in. by 36 in., of R.A.F. 15 section, with a single slot. A systematic exploration of the effect of varying the position of the leading aerofoil (corresponding with the portion of the wing in front of the slot) in relation to the main aerofoil has been made over a range of wind speeds between 20 and 90 ft./sec. In addition, some auto-rotation experiments were made for comparison with similar experiments on the standard R.A.F.15 aerofoil. As a result of variation in the position of the leading aerofoil, the maximum lift coefficient was increased from the figure for maximum lift coefficient of 0·85 obtained by Messrs. Handley Page for the same sections of main and leading aerofoils to nearly 0·9. The speed effect on the arrangement tested was found to be considerable at the lower speeds, but between 65 and 90 ft./sec. it was very slight below the stall and not great above the stall. The maximum auto-rotative couples on the slotted aerofoil were nearly four times those on the R.A.F.15 aerofoil; the range and speed of auto-rotation were also much greater, although auto-rotation did not begin until a large angle of incidence was reached. There is a possibility that difficulty in control may arise at low speeds with the full-scale aeroplane, and such is indicated by the model experiments and needs investigation. The model research will be continued at Teddington on the sections R.A.F.26 and 31. The report, No. 929, is obtainable from any of the branches of H.M. Stationery Office. Price 1s. net.

CATALOGUES.

Automatic Machine Tools.—A catalogue of automatic screwing and turning machines, showing a good range of simple automatic types has come to hand from the Maison Cornèlis Company, Liege, Belgium. The text is in French.

Combined Switch and Fuse.—A leaflet illustrating and describing the parts of a new quick make and break switch with fuses has come from the General Electric Company, Limited, Magnet House, Kingsway, London, W.C. Dimensions and a variety of applications are mentioned, with prices.

Type-Composing Machines.—The Lanston Monotype Corporation, Limited, 43, Fetter-lane, London, E.C.4, have sent us a further copy of their house journal containing articles on the construction and operation of their machines and matters of general interest to printers.

Steam Fittings.—A card showing illustrations of stop valves, safety valves, reducing valves, engine indicators, pressed steel unions with bronze seats and instruments for measuring pressure and temperature, is to hand from the Crosby Valve and Engineering Co., Limited, 42, Foley-street, London, W.1.

Evaporators.—Messrs. Mirrlees Watson and Co., Limited, Scotland-street, Glasgow, have sent us a catalogue describing the construction of their evaporators for manufacturing processes, such as sugar making, and a continuously-operating syrup sampling apparatus used with the multiple-effect evaporators.

Comparator.—An instrument for comparing two spectra as an easy and rapid means for determining in analysis the presence or absence of lines, is described and illustrated on a card received from Messrs. Adam Hilger and Co., Limited, 75a, Camden-road, London, N.W.1. The negatives may be examined wet and direct from the fixing bath.

Air Preheater for Boiler Furnaces.—A catalogue of the apparatus for preheating air supplied to steam boilers is to hand from Howden-Ljungström Preheaters (Land) Limited, 133, Helen-street, Govan, Glasgow. This apparatus was originally described in ENGINEERING, vol. cxiv, page 24. It transfers the heat of the waste flue gases to the air entering the furnaces. The claims made for it, in point of fuel economy and easy operation, will command the attention of engineers.

Coal Mining Machinery.—Messrs. Mavor and Coulson, Limited, 47, Broad-street, Mile End, Glasgow, have sent us a further issue of their journal "Machine Mining," which is full of relevant matter of practical value and of general interest in this particular branch of engineering. A graphical presentation of their trade shows that the firm established only a nominal sale of their machines in the first seven years and that this has been followed by twenty-one years of steady expansion.

Non-Ferrous Metals.—A little book giving information concerning the properties and uses of non-ferrous metals and alloys has been received from Messrs. Kynoch, Limited, and King's Norton Metal Co., Limited, Birmingham. The general descriptive matter is clear and practical, particularly that dealing with the methods of working (including press work) for which various classes of strip, sheets, rods and wires, are suitable. In addition there are many reference tables which will frequently be of service to engineers.

Temperature Indicators.—A new catalogue of thermo-electric pyrometers received from the Cambridge Instrument Co., Limited, 45, Grosvenor-place, London, S.W.1., illustrates a number of recording indicators in strong metal cases adapted for fixing to walls or other supports and proof against moisture and fumes. From one to six records can be made simultaneously and synchronously from several points on a single chart; the records may be all of temperature or some of them may give percentages of CO_2. The catalogue contains a specimen chart and much excellent explanatory matter.

Manganese Steel.—The extending applications of manganese steel render it necessary for the steel maker to produce finished parts ready to put in place, as he can overcome most satisfactorily the difficulties of working a material that is not amenable to the cutting and working tools in common use. This point is well illustrated in a number of catalogues received from Messrs. Hadfields, Limited, Sheffield, dealing with tram rails and connections, axles, special parts for dredgers, including pins and bushes, buckets, bucket lips, tumblers and tumbler shafts, connecting links, grubbers, &c., of manganese steel. Most of these parts are subject to exceptional abrasive action, and manganese steel can be very largely employed for their construction. As an example, the ordinary pins for connecting links are shown, and one, made of steel which would be quite satisfactory for years in ordinary machinery, has been worn down to the danger limit by three months' work in a dredger. A manganese steel pin, on the other hand, shows far less wear after three years' service.

RAPID HARDENING CEMENT.—The use of the British rapid hardening cement, known as "Ferrocrete," to which we have previously referred in our columns, appears to be increasing. Recently the material was adopted for the relaying of the portion of Piccadilly extending from Park-lane to Brick-street. Other applications decided on include the Nechells power station extension at Birmingham and the development of the Bedford Corporation Electricity Works. For the former operations an order for 400 tons of "Ferrocrete" has been placed with the Cement Marketing Company, Limited, of Tothill-street, Westminster, London, S.W.1.